FINAL REPORT

Properties, Occurrence and Management of Soils with Vesicular Surface Horizons

Contract No. 52500-CT5(N)

Between

USDI, Bureau of Land Management

and

Nevada Agricultural Experiment Station

By: R.E. Eckert, Jr.
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SUMMARY AND RECOMMENDATIONS

This report summarizes 2 years' work on the occurrence, properties, and management of soils with vesicular surface crusts.

Within the big sagebrush/grass type, four kinds of surface soil morphologies were found on certain Xerollic Argids: noncrusted Type I, on coppice dunes; noncrusted Type II, on coppice benches; crusted Type III on intercoppice microplains; and crusted Type IV on playettes. These four soil surface types are consistently related to microtopographic position and exhibit differences in both external shrinkage polygon physiognomy and internal soil morphology. The coverage of each type varies among study sites. In the first year of study, only a noncrusted "coppice" surface type (composed of Types I and II) and a crusted "interspace" surface type (composed of Types III and IV) were recognized and evaluated. During the second year, all four types were distinguished.

The vesicular crusts of A11 horizons found in the interspaces between coppice dunes are massive and overlie A12 horizons with platy structure. These horizons are silt loams, with up to 50% silt and very fine sand. The crusts have a higher modulus of rupture, higher bulk density, and lower seedling emergence than the noncrusted A11 horizon. The coppice soil[1/] has more organic matter than does the interspace soil. The pH of coppice soil ranges from slightly acid to slightly basic and was similar to the pH of interspace soils. When organic matter was removed from coppice soil, the resultant soil had a high modulus of rupture, high bulk density, and very low seedling emergence, similar to interspace soil. Crested wheatgrass and squirreltail seedlings show a high degree of stress during germination and emergence from interspace soil at high moisture tensions. Little or no stress is evident in coppice soil or in moist interspace soil. Plowing

1/ For brevity, the A11 horizon soil material is called simply "coppice soil" or "interspace soil".

did not increase grass seedling emergence at any site. In fact, plowing reduced emergence at two sites. Grass emergence was much greater from Type 1 (coppice) and Type 11 (coppice bench) soils than from Type 111 (intercoppice microplain) or Type 1V (playette) soils. Crested wheatgrass had the best emergence of all grass species tested, followed closely by squirreltail. Emergence of Thurber needlegrass was much lower than both other grasses. The deep-furrow drill gave the best emergence of all species on all soil surface types at three sites, followed closely by the standard drill. The standard drill was superior at the one location with a high proportion of Type 111 soil. The broadcast-simulated cow trampling treatment was significantly lower. The broadcast-no simulated cow trampling treatment essentially failed. Acceptable stands of four-wing saltbush were obtained on two sites by the deep- and standard-drill techniques on unplowed soil and at three locations by the same seeding techniques on plowed soil. Crown growth of this shrub was greatest in plowed soil. The best established stands were obtained from crested wheatgrass. Best stands of all seeded grasses were found in deep furrows in Type 1 and 11 soils. Poorest stands were found on sites with a large proportion of Type 111 soil.

Results from the greenhouse and seeding studies lead to the following conclusions:

1. Increased organic matter content and low soil moisture tensions favor emergence from vesicular crusts.
2. Sites with a large proportion of Types 1 and 11 surfaces should be first choice for seeding projects. Brush control with herbicides and deep-furrow seeding should give good results.

3. Deep- and standard-drilling techniques were far superior to broadcasting techniques.
4. Soil disturbance by plowing as a means of seedbed preparation or use of deep furrows for seeding is not recommended on sites with a large proportion of intercoppice microplain or playette type soil surfaces. Brush control by herbicides and seeding with a standard-furrow drill should give good results on Type 111 surface. The Type 1V surface is a very difficult site for seedling establishment.
5. Species with high emergence potential, such as crested wheatgrass and squirreltail, should be used for seeding sites with a large proportion of Type 111 vesicular crust.

The off-road vehicle trials were made on soils with different surface soil morphologies than on the seeding sites. The off-road sites have either a Type V (imbedded gravel pavement) or a Type V1 (loose gravel mulch) on the intercoppice microplain and playette positions rather than barren, fine earth as at the seeding sites. A Type V11 (animal spoil) surface is also found on the coppice and coppice bench positions at the off-road sites.

In 2 of the 3 off-road vehicle trials, runoff was similar between study sites. Suspended sediment, however, was always greater in the runoff water from the Blue Diamond site than from the Crystal Springs site. This difference was at least partially a function of the soil surface type of the interspace area. At Blue Diamond, some mineral soil is exposed to raindrop impact and is subject to detachment and movement of soil particles. At Crystal Springs, a gravel mulch covers most of the interspace surface and protects the mineral soil from raindrop impact.

In general, more water ran off treated areas after soil had been disturbed, wet, and the soil allowed to dry and the crust to reform. However, runoff after crust reformation contained the same amounts of sediment as did the runoff water after the initial treatment. Evidently the reformed crust had reduced infiltration, but the new crust was more resistant to particle detachment by raindrop impact. This characteristic may change over time due to weathering actions, such as freezing, thawing, and frost heaving.

Multiple-vehicle traffic greatly reduced the infiltration capacity and increased sediment production. Both runoff and sediment were much greater from interspace soil than from coppice soil. The greatest amount of runoff and sediment came from interspace soil after crust reformation.

The sites studied have gentle slopes. Runoff water and sediment from the area around the infiltration plot generally collects in an adjacent interspace. Therefore, runoff and sediment from large off-road vehicle events on gentle slopes probably would not move off-site. On steeper slopes, however, much of the sediment produced should be found in the drainage, especially if vehicle tracks run perpendicular to the slope.

Evaluation of vegetation damage from multiple-vehicle traffic showed that the dominant and/or palatable shrubs such as white bursage, creosote bush, joint-fir, range ratany, blackbrush, and spiny hopsage were severely injured or killed. Undesirable species, such as box thorn and snakeweed, were only partially injured and made vigorous regrowth.

These results suggest the following recommendations for off-road vehicle use:

1. Restrict travel or events on soils with an imbedded pavement similar to that at the Blue Diamond site. Soils with a gravel mulch, such as at Crystal Springs, appear to be more compatible

with off-road traffic.

2. Use the same areas for casual off-road vehicles and organized events, rather than dispersing traffic and destroying the watershed of many areas.
3. Select areas with a high proportion of coppice type surface soil and gravel-mulched interspace for off-road traffic.
4. Select areas with minimum slope for all off-road traffic.

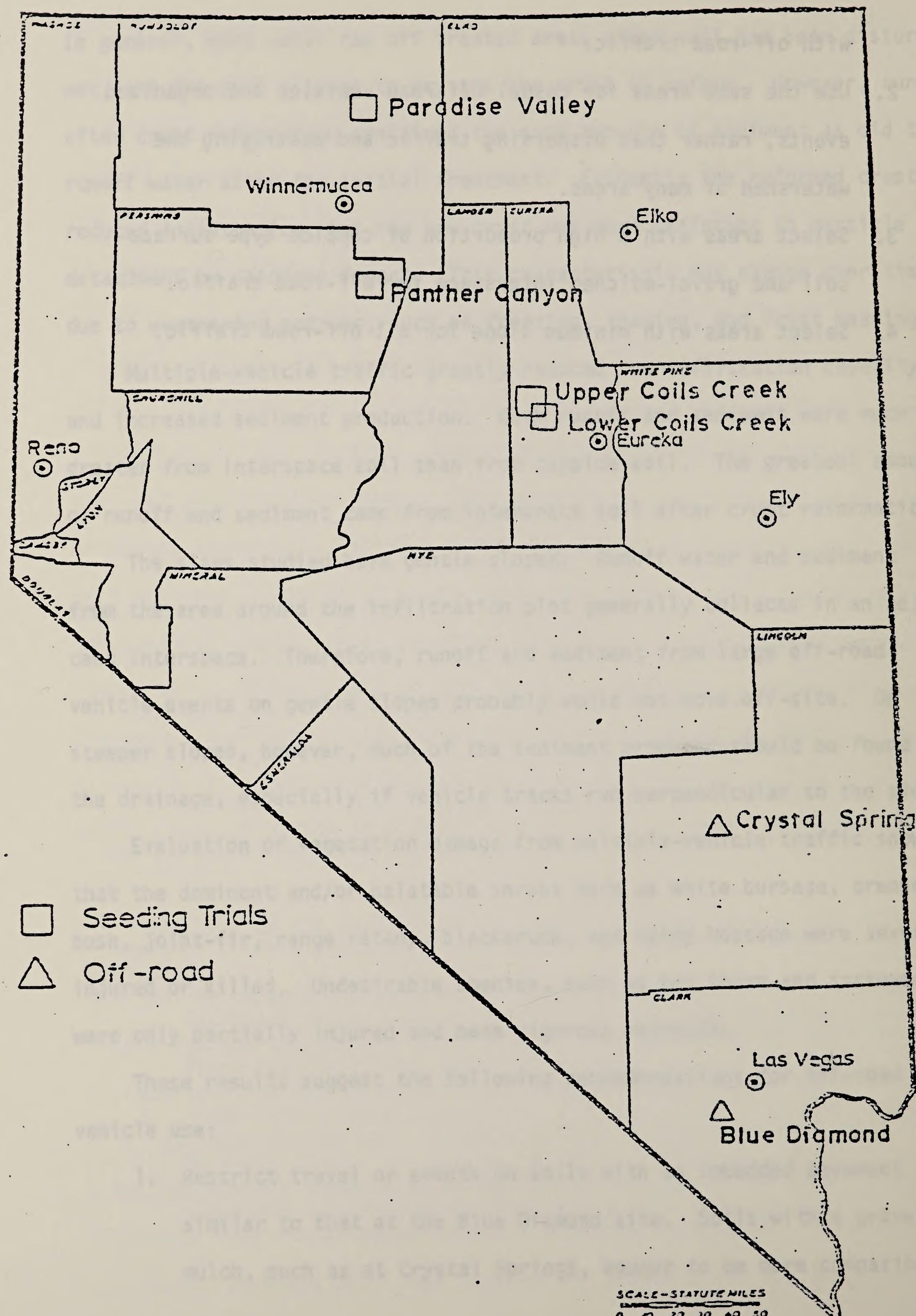

Figure 1. Location of seeding trials and off-road vehicle study sites.

PROPERTIES, OCCURRENCE, AND MANAGEMENT OF SOILS WITH VESICULAR SURFACE HORIZONS

Richard E. Eckert, Jr., Frederick F. Peterson, Martin K. Wood, and Wilbert H. Blackburn

INTRODUCTION

High intensity, short-duration summer thunderstorms account for most of the runoff and sediment from arid and semi-arid rangelands. The amount of runoff and sediment loss depends on vegetative cover and the extent and surface morphology of coppice dune and dune interspace soils.

The coppice dune is the area of accumulation of litter and wind-blown soil under trees, shrubs, and bunchgrasses in arid and semi-arid regions. This soil surface is non-crusted, very slightly hard, and has very fine subangular blocky structure. The dune interspace is the area between coppice dunes, and has a massive, crusted surface with degrees of vesicular porosity. Soil properties associated with vesicular crusts cause low infiltration rates with resultant high runoff and potential high sediment production.

Objectives of this study are: 1) to characterize different types of soil surfaces of Aridisols, 2) to evaluate methods to increase vegetative cover and the amount of coppice dune through revegetation techniques, and 3) to determine the effects of off-road vehicle traffic on infiltration and sediment production of soils with gravel-mulched or paved vesicular crusted surface horizons. Field study sites are shown in Figure 1. This completion report presents results for the period 1974-1976.

LABORATORY AND GREENHOUSE STUDIES

METHODS

Seedling emergence characteristics in relation to surface soil properties were evaluated on soil from the Coils Creek watershed.

Seedling Stress During Emergence

Seed of crested wheatgrass (*Agropyron desertorum*) and squirreltail (*Sitanion hystrix*) was planted in coppice dune and dune interspace soil under greenhouse conditions. Two watering schedules were used: once every 3 days and once every 6 days. After 3 weeks, total emergence was determined, and each seedling was rated for the amount of stress developed during emergence according to the following scale:

1. No stress - Coleoptile longer than 2.5 cm and straight, root development normal.
2. Slight stress - Coleoptile length greater than 2.5 cm but the coleoptile or roots slightly wavy.
3. Moderate stress - Coleoptile length less than 2.5 cm but greater than 1.0 mm. Coleoptile and roots with prominent waviness.
4. Heavy stress - Coleoptile length less than 2.5 cm but greater than 1.0 mm. Coleoptile or root growth retarded.
5. Extreme stress - Germination started but stopped immediately. Elongation less than 1 mm.
6. Failure - Seed did not germinate.

Organic Matter

Organic matter was either removed from or added to coppice and interspace soils. Removal was accomplished by boiling soil in hydrogen peroxide (H_2O_2). Soils boiled in water and untreated soil were also evaluated.

Organic matter was increased by 2% increments to 14% by weight by additions of leaves of sagebrush and bunchgrass. After both removal and addition treatments, samples of each soil were subjected to several wetting and drying cycles. Percent organic matter, bulk density, and modules of rupture were determined on a portion of each sample. Seed of crested wheatgrass was also planted in a sample of each soil. Soil with organic matter removed and organic matter added treatments each received two watering treatments: once every day and once every 3 days; and once every 2 days and once every 4 days, respectively.

RESULTS AND DISCUSSION

Seedling Stress During Emergence

Emergence of crested wheatgrass was 88% in coppice and 15% in interspace soil watered every 3 days. Emergence was 80% and 3% in coppice and interspace soil watered every 6 days, respectively. Emergence of squirreltail was 58% in coppice and 5% in interspace soil watered at 3-day intervals and 45% and 0% in interspace soil in the 6-day watering treatment (Table 1).

Table 1. Mean percent emergence for crested wheatgrass and squirreltail seedlings in coppice and interspace soils watered every 3 and 6 days.

Soil	Watering Cycle (days)	Percent Emergence 1/	
		Crested Wheatgrass	Squirreltail
Coppice	3	88 a	58 a
	6	80 a	45 a
Interspace	3	15 b	5 b
	6	3 b	0 b

1/ Means with the same letter are not significantly different at the .05 level of probability as determined by Duncan's Multiple Range Test. Comparisons are made within column.

Crested wheatgrass and squirreltail grown in coppice soil and watered either every 3 days or 6 days showed the least amount of stress while seedlings grown in the interspace soil showed significantly higher stress (Table 2).

Stress values for squirreltail were slightly higher than for crested

Table 2. Mean stress for crested wheatgrass and squirreltail seedlings in coppice and interspace soils watered every 3 and 6 days.

Soil	Watering Cycle (days)	Stress Rating[1/]	
		Crested Wheatgrass	Squirreltail
Coppice	3	1.57 a	2.30 a
	6	1.85 a	2.35 a
Interspace	3	3.83 b	4.20 b
	6	4.7 b	5.60 b

1/ Means with the same letter are not significantly different at the .05 level of probability as determined by Duncan's Multiple Range Test. Comparisons are made within column.

wheatgrass. Both species grown in coppice soil and watered every 3 days had a high proportion of seedlings in the no stress to moderate stress category (Fig. 2). In the interspace soil a high proportion of seedlings were in the moderate to extreme stress category. When watered every 6 days, both species showed a trend similar to the 3-day watering regime in coppice soil while most seedlings in the interspace soil showed extreme stress and some seeds did not germinate (Fig. 3).

Organic Matter

Boiling soils in hydrogen peroxide reduced the organic matter of the coppice to the level of the interspace soil and only slightly reduced the organic matter content of the interspace soil (Table 3). Litter additions increased organic matter content of coppice soil from a base level of 5.1% to 12.4% and of interspace soil from a base level of 1.3% to 9.9%.

Generally, bulk density decreased with the number of wetting and drying cycles. This was particularly true of the untreated interspace soil and coppice soil with organic matter removed and suggest that, with repeated wetting and drying of soil low in organic matter, the density of these soils will decrease, provided further disturbance is prevented, while vesicularity

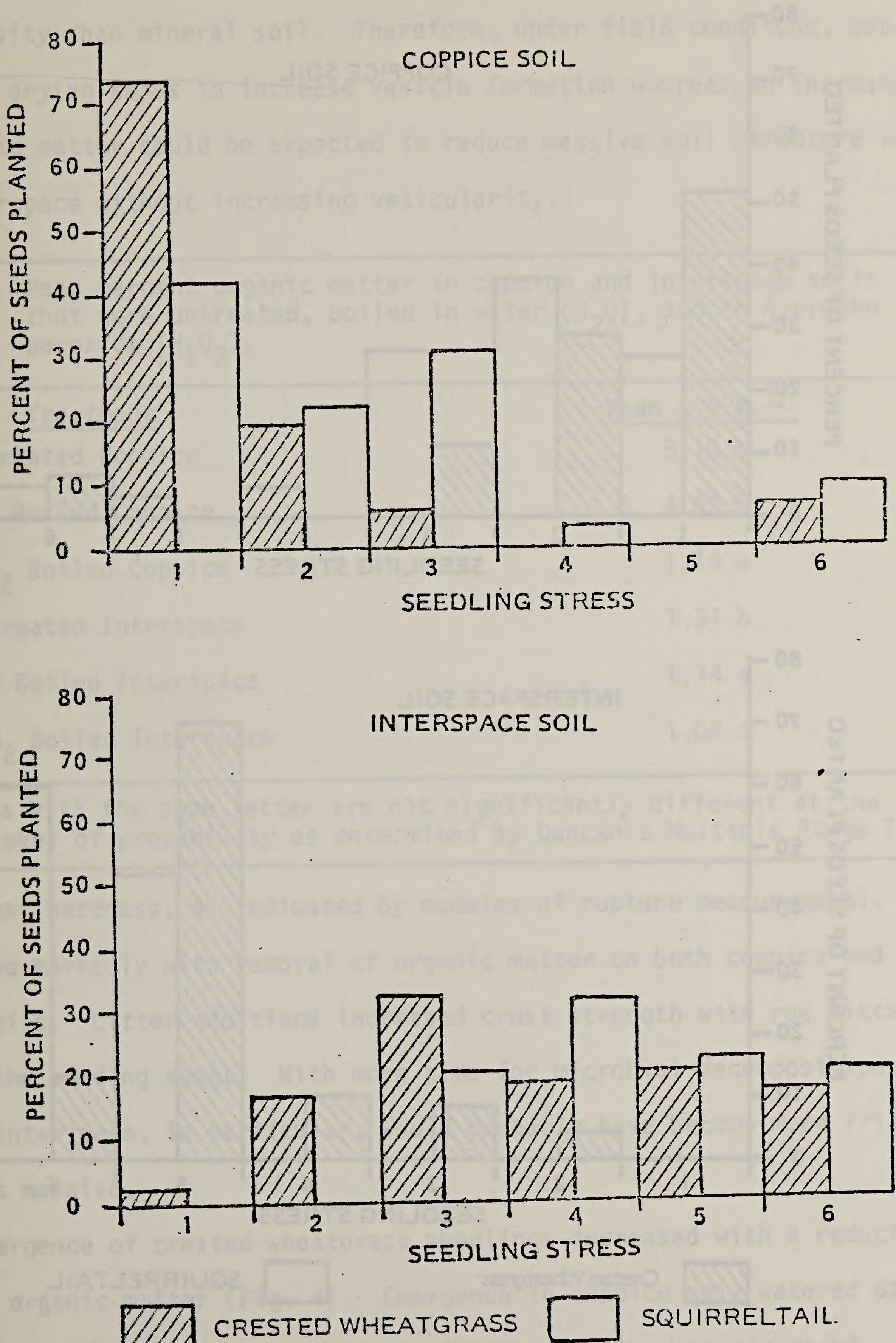

Figure 2. Seedling stress of crested wheatgrass and squirreltail when planted in coppice and interspace soils and watered every three days.

1 = no stress
2 = slight stress
3 = moderate stress
4 = heavy stress
5 = extreme stress
6 = failure

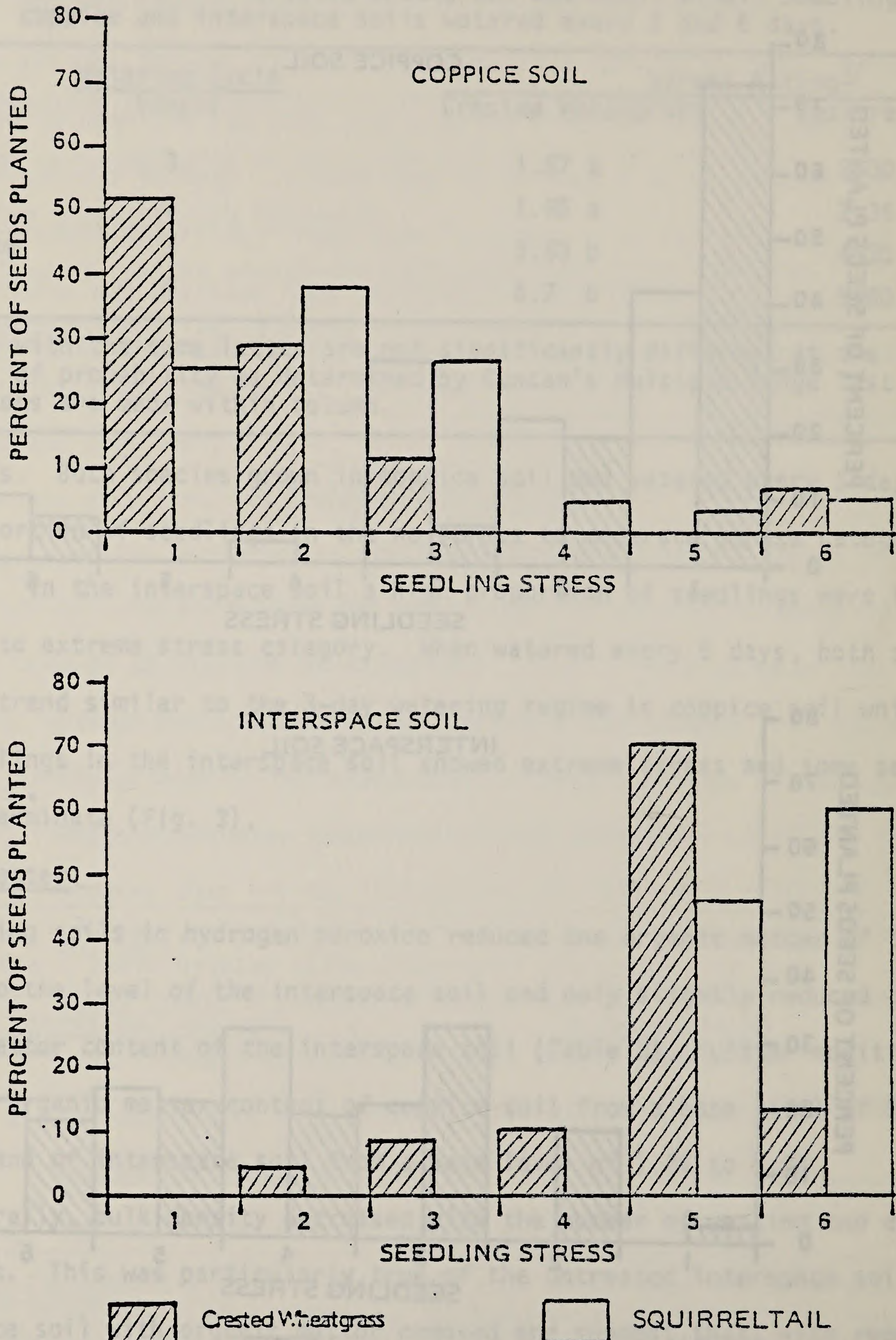

Figure 3. Seedling stress of crested wheatgrass and squirreltail when planted in coppice and interspace soils and watered every six days.

1 = no stress
2 = slight stress
3 = moderate stress
4 = heavy stress
5 = extreme stress
6 = failure

increases. Bulk density of both coppice and interspace decreased with increases in organic matter, probably because organic matter has a lower bulk density than mineral soil. Therefore, under field conditons, wetting and drying tends to increase vesicle formation whereas an increase in organic matter could be expected to reduce massive soil structure in the interspace without increasing vesicularity.

Table 3. Mean percent organic matter in coppice and interspace soils that were untreated, boiled in water (H_2O), and in hydrogen peroxide (H_2O_2).

Treatment	Mean % O.M.[1/]
Untreated Coppice	5.10 b
H_2O Boiled Coppice	4.63 b
H_2O_2 Boiled Coppice	1.14 a
Untreated Interspace	1.31 b
H_2O Boiled Interspace	1.14 a
H_2O_2 Boiled Interspace	1.09 a

1/ Means with the same letter are not significantly different at the .05 level of probability as determined by Duncan's Multiple Range Test.

Crust hardness, as indicated by modules of rupture measurements, increased markedly with removal of organic matter on both coppice and interspace soils. Litter additions increased crust strength with raw litter acting as the binding agent. With more time for microbial decomposition to occur, interspace, in particular, would probably have become more friable and less massive.

Emergence of crested wheatgrass seedlings decreased with a reduction in soil organic matter (Fig. 4). Emergence in coppice soil watered daily was 94% compared to 76% in coppice soil with organic matter removed. A large reduction in emergence occurred in both soils when the watering interval was increased to every 3 days. For example, emergence in coppice

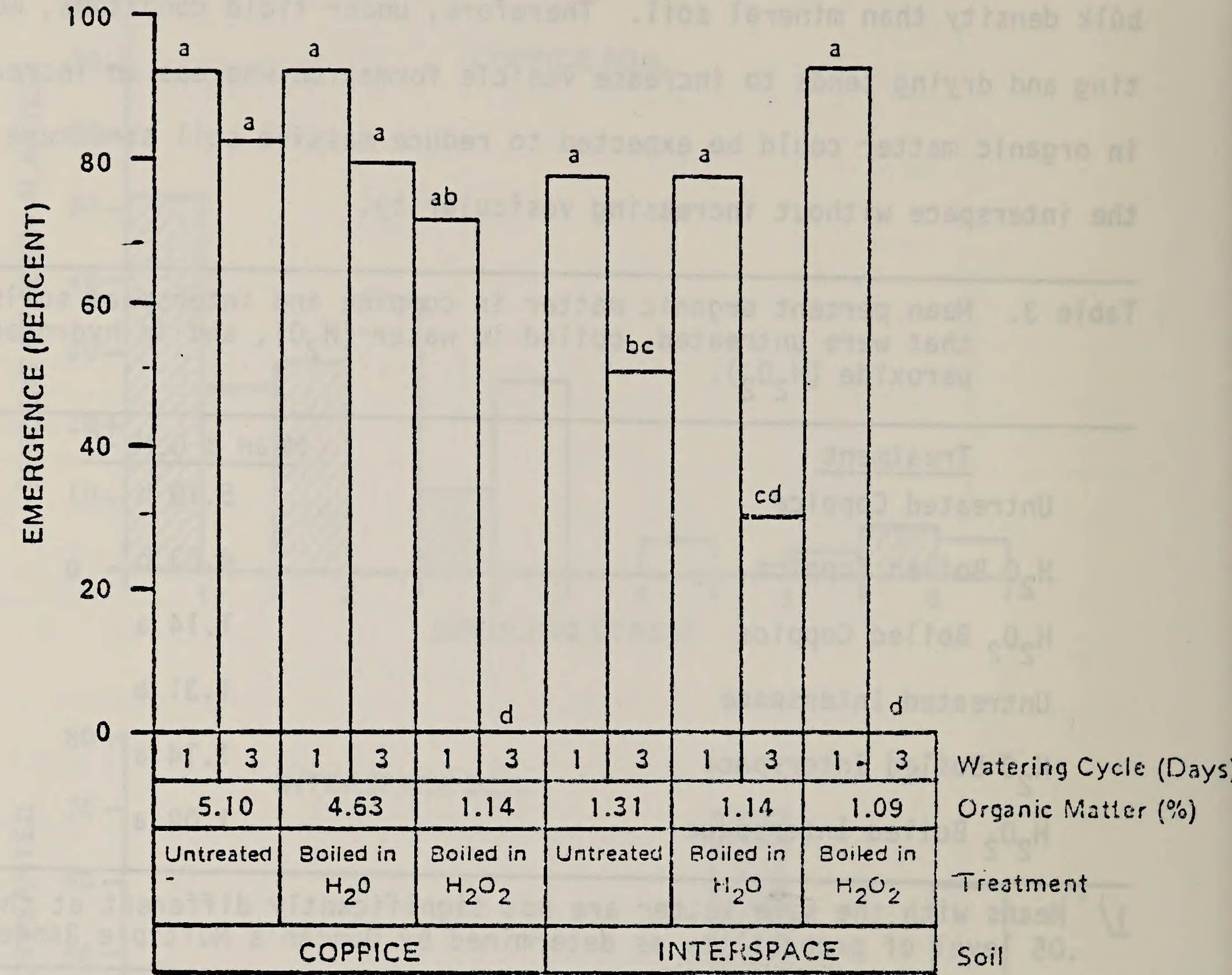

Figure 4. Percent emergence of crested wheatgrass planted in untreated, water (H_2O) boiled, and hydrogen peroxide (H_2O_2) coppice and interspace soils. Means with the same letter are not significantly different at the .05 level of probability as determined by Duncan's Multiple Range Test.

soil with reduced organic matter was 70 and 0% when the watering frequency was daily and every 3 days, respectively. Interspace soil showed the same response to watering frequency.

In summary, emergence of crested wheatgrass and squirreltail seedlings was much lower in the surface horizon of interspace soil with vesicular porosity than in coppice soil. Interspace soil kept moist had good seeding emergence, however. Reductions in organic matter content caused higher bulk density, greater crust strength, and reduced seedling emergence. Additions of organic matter improved the growth-medium characteristics of interspace soil. These results suggest that organic matter is an important factor in preventing the formation of vesicular surface horizons. Field studies therefore were directed toward development of methods to improve vegetative cover and organic matter, particularly on interspace soils, to reduce the adverse impacts of this kind of soil surface on seedling emergence and watershed characteristics.

SEEDING STUDIES

SITE DESCRIPTION

Location

Four 0.5 hectare seeding exclosures were established in northern Nevada in Fall, 1974. These are located as follows: two sites at Coils Creek about 50 km northwest of Eureka; one site at Panther Canyon about 48 km south of Winnemucca; and one site in Paradise Valley about 65 km north of Winnemucca (Fig. 1). All sites are located in the big sagebrush (*Artemisia tridentata*) type.

Precipitation

Precipitation from October, 1974 to June, 1975 was: Lower Coils Creek, 18.0 cm, Upper Coils Creek, 22.1 cm; Panther Canyon, 24.1 cm; and Paradise Valley, 17.3 cm. Precipitation from June, 1975 through May, 1976 was considerably lower than for the previous year: Lower Coils Creek, 11.8 cm; Upper Coils Creek, 14.2 cm; Panther Canyon, 9.7 cm; and Paradise Valley, 9.4 cm. However, whereas precipitation during winter and spring of 1976 appeared to reduce total emergence compared to 1975, the above average precipitation in June, July, and August probably increased survival and did result in the fall germination and emergence of many seeds that did not germinate the previous spring. Summer precipitation amounts were: Lower Coils Creek, 9.0 cm; Upper Coils Creek, 8.5 cm; Panther Canyon, 14.4 cm; and Paradise Valley, 14.0 cm.

Vegetation

Shrub cover is highest at Lower Coils Creek (Table 4), with a crown cover of big sagebrush (23.9%), low sagebrush (*Artemisia arbuscula*) (1.7%), and rabbitbrush (*Chrysothamnus viscidiflorus*)(0.2%). Shrubs at Lower Coils Creek are big sagebrush (22.2%) and low sagebrush (1.4%). Shrubs

at Panther Canyon are big sagebrush (19.3%) and spiny hopsage (Grayia spinosa) (1.1%). Shrub cover is lower at Paradise Valley with big sagebrush (15.5%) and horsebrush (Tetradymia canescens) (0.2%).

Perennial grass cover is greatest at Panther Canyon (Table 5). Grasses are Sandberg bluegrass (Poa sandbergii) (6.7%), squirreltail (1.8%), and Great Basin wildrye (Elymus cinereus) (0.7%). Second highest cover is at Upper Coils Creek with a basal cover of Webber ricegrass (Oryzopsis webberi) (1.6%), Sandberg bluegrass (1.5%), and squirreltail (0.7%). Perennial grass cover at Paradise Valley is crested wheatgrass (0.7%), squirreltail (0.5%), and Sandberg bluegrass (0.4%). Perennial grasses at Lower Coils Creek are Sandberg bluegrass (1.1%) and squirreltail (.02%).

Annual plant cover at Panther Canyon is mainly cheatgrass (Bromus tectorum) (4.4%) (Table 6). Second highest cover is at Paradise Valley with tumble mustard (Sysymbrium altissimum) (0.5%) and cheatgrass (1.3%) most important. No annual species are present on the Coils Creek sites.

Table 4. Mean percent crown cover of shrubs at the four study sites.[1/]

	Percent
Lower Coils Creek	23.4 ab
Upper Coils Creek	23.9 a
Panther Canyon	20.4 ab
Paradise Valley	15.5 b

1/ Means followed by the same letter are not significantly different at the .05 level of probability as determined by Duncan's Multiple Range Test

Table 5. Mean percent basal area cover of perennial grasses at the four study sites.[1/]

	Percent
Lower Coils Creek	1.1 a
Upper Coils Creek	3.8 b
Panther Canyon	9.2 c
Paradise Valley	1.5 a

1/ Means followed by the same letter are not significantly different at the .05 level of probability as determined by Duncan's Multiple Range Test.

Table 6. Mean percent basal cover of annual plants at the four study sites.[1/]

	Percent
Lower Coils Creek	0 a
Upper Coils Creek	0 a
Panther Canyon	4.4 b
Paradise Valley	1.8 a

1/ Means followed by the same letter are not significantly different at the .05 level of probability as determined by Duncan's Multiple Range Test.

Soil

Based on soil profile descriptions (Appendix I) and laboratory characterizations (Appendix II), soils at the four study sites were classified as follows:

Lower Coils Creek: fine, montmorillonitic, mesic Xerollic Nadurargid

Upper Coils Creek: a complex of fine, montmorillonitic, mesic Xerollic Durarigids; and fine, montmorillonitic, mesic Xerollic Nadurargids

Panther Canyon: fine, montmorillonitic, mesic, Xerollic Nadurargid

Paradise Valley: fine-loamy, mixed, mesic Xerollic Nadurargid.

At Lower Coils Creek sand is higher in coppice soil (55%) than in interspace soil (44%). Total sand content of coppice is higher than any other site. Total sand content of interspace is second highest among sites. The amount of silt in coppices (33%) is lower than in interspace (36%). The small amount of total silt in coppice and interspace is lowest of any site. Clay content of coppices (12%) is lower than interspace (20%). Clay content is lowest in coppice and second highest in interspace soil for all sites.

At Upper Coils Creek, sand is higher in coppice soil (36%) than in interspace soil (29%). Total sand content of coppices and interspaces is lowest of any site. The amount of total silt in coppice (48%) and interspaces (49%) is similar. Total silt content of coppices and interspaces is highest among sites. The amount of clay in coppices (16%) is lower than in interspaces (22%). Clay content of coppice and interspace is highest among sites.

At Panther Canyon, sand in coppice soil (46%) and in interspace soil (47%) is similar. The amount of sand is second highest at Panther Canyon in coppice and highest in interspace. Total silt content in coppice (38%) and interspace (37%) is similar. The amount of silt is second lowest among sites in coppice and interspace. Clay content in coppice (16%) is the same as clay in interspace. The amount of clay is second lowest in coppice and equal to highest clay in interspace.

At Paradise Valley, the amount of sand in coppice soil is the same as in interspace (42%). Total sand content at Paradise Valley is second lowest among sites in coppices and interspaces. The amount of total silt in coppice (44%) is similar to that in interspace (46%). Total silt content of coppice and interspace is the second highest among sites.

The amount of clay in coppices (14%) is similar to that in interspace (12%). Clay content of coppices and interspaces is second lowest and lowest among sites, respectively.

Plaques made from interspace soils are significantly harder than those made from coppice soils at all sites (Table 7). Essentially, little or no pressure was required to break plaques of coppice soils from any site. Hardest interspace soil is from Panther Canyon. Second hardest is from Lower Coils Creek. Plaques of this soil are significantly harder than that from Upper Coils Creek and Paradise Valley soils.

Interspace soils have a higher bulk density than coppice soil at all sites. Bulk density of interspace soil at Lower Coils Creek and Paradise Valley is significantly higher than that of Upper Coils Creek and Panther Canyon. Coppice soils at all sites have similar bulk densities.

Organic matter is higher in the coppice soils than in the interspace soils at all sites. The coppice (5.82%) and the interspace (2.12%) soils from Upper Coils Creek contain the greatest amount of organic matter in each soil type. Coppice (3.46%) and interspace (0.55%) soils from Paradise Valley have the smallest amounts of organic matter.

The pH values of both coppice and interspace soils at all sites are near neutral. However, the pH of interspace soils is higher than that of coppice soil at all sites except Lower Coils Creek where the reverse is true. The markedly higher pH values of a 1:5 suspension compared to those of a saturated paste suggest the presence of significant amount of exchangeable sodium or potassium from plant litter.

Soil Surface Morphological Types

Two types of surficial soil horizons were recognized at the start of the current study: Type 1 (coppice dune) and Type 111 (dune interspace).

Table 7. Mean modulus of rupture and bulk density of Type 1 (coppice) and Type 111 (interspace) surface soils at each seeding trial site.

Seeding Site	Soil	Modulus of Rupture	Bulk Density
		millibars	g/cm³
Lower Coils Creek	Type 1	17.6 b 1/	0.90 c 1/
	Type 111	75.9 d	1.42 a
Upper Coils Creek	Type 1	0.0 a	0.83 c
	Type 111	61.4 c	1.25 b
Panther Canyon	Type 1	4.7 a	0.87 c
	Type 111	84.4 d	1.25
Paradise Valley	Type 1	0.0 a	0.90 c
	Type 111	56.0 c	1.36 a

1/ Means in each colum followed by the same letter are not significantly different at the .05 level of probability as determined by Duncan's Multiple Range Test.

Surface coverage of each soil type in the 1974-75 seeding plots is shown in Table 8. Type 1 cover is lower than Type 111 cover at all sites. Type 1 is similar at Lower Coils Creek, Upper Coils Creek, and Panther Canyon. Type 111 cover is similar at the same sites. At Paradise Valley, Type 1 cover is significantly lower and Type 111 cover higher than at the other three sites.

Later field studies defined four possible surficial horizon types by subdividing the two recognized in 1974-75. These four types are distinguished by different degrees of crust expression. They occur in different proportions on various soils, and can be distinguished by eye from their surface features.

The four surface soil morphological types are genetically related to their microtopographic position, or micro-landform, and thus can be identified in part by their microtopographical positions. The major types are listed in Table 9 by Roman numerals which serve as names for them. It is

Table 8. Mean percent are cover of Type 1 (coppice dune) and Type 111 (dune interspace) surficial soil at the four study sites.1/

	Type 1	Type 111
	% Cover	% Cover
Lower Coils Creek	43.2 b	56.8 a
Upper Coils Creek	38.5 b	61.5 a
Panther Canyon	38.2 b	61.8 a
Paradise Valley	15.6 a	84.4 b

1/ Means followed by the same letter are not significantly different at the .05 level of probability as determined by Duncan's Multiple Range Test.

important to name these soil surface morphological types by their Roman numeral rather than their microtopographic position since other soil surface morphological types occur on the same microtopographic positions elsewhere, and these surface types occur on somewhat different microtopographic positions on hill slopes. A detailed description of each surface type is presented in Appendix I. Schematic diagrams are given for polygon shape and morphology (Fig. 5) and for the microtopographic positions (Fig. 6) that have been defined for alluvial fan remnants within the Humboldt loess area. Surface cover of each soil surface morphological type in the 1975-76 seeding trials is shown in Table 10.

Within the limited variety of Argids represented by our seeding sites, soil morphological differences among the four soil surface types recognized consist of (1) external polygon physiognomy, and (2) internal soil morphology and thickness of the very surface, or A11 horizon. The polygons, named after their outlines at the soil surface, are actually the massive tops of squat, very coarse prisms, that extend down through the entire A horizon, or epipedon and in some cases, on into the B horizon. They are attributed to recurrent soil shrinking and fracture along the same semi-vertical planes, or prism faces. These prism faces are clearly expressed in the A11 horizon,

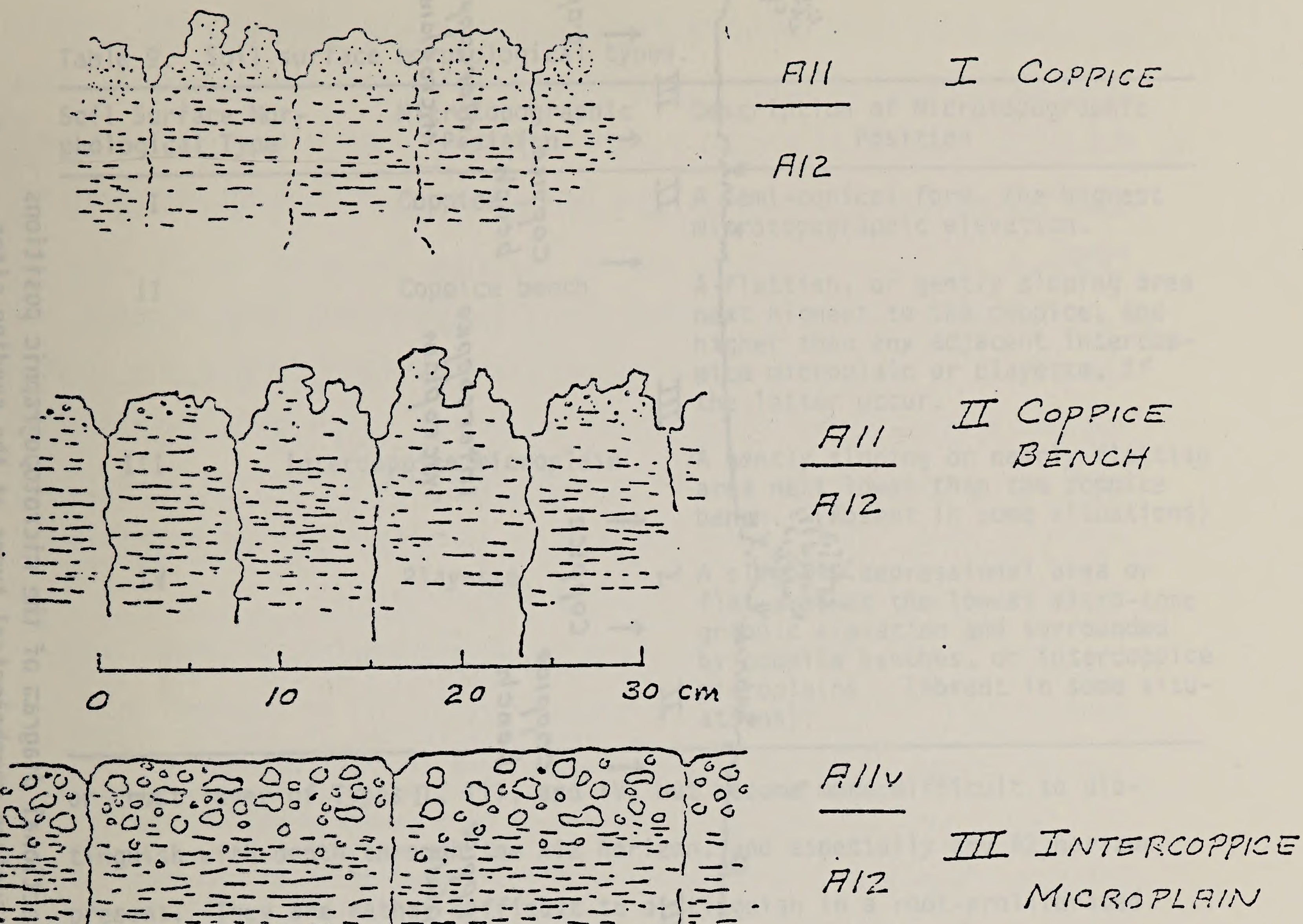

Figure 5. Schematic cross-sectional diagram of the common shrinkage polygon shapes and morphologies for the major soil surface morphology types at the seeding sites in the Humboldt loess area.

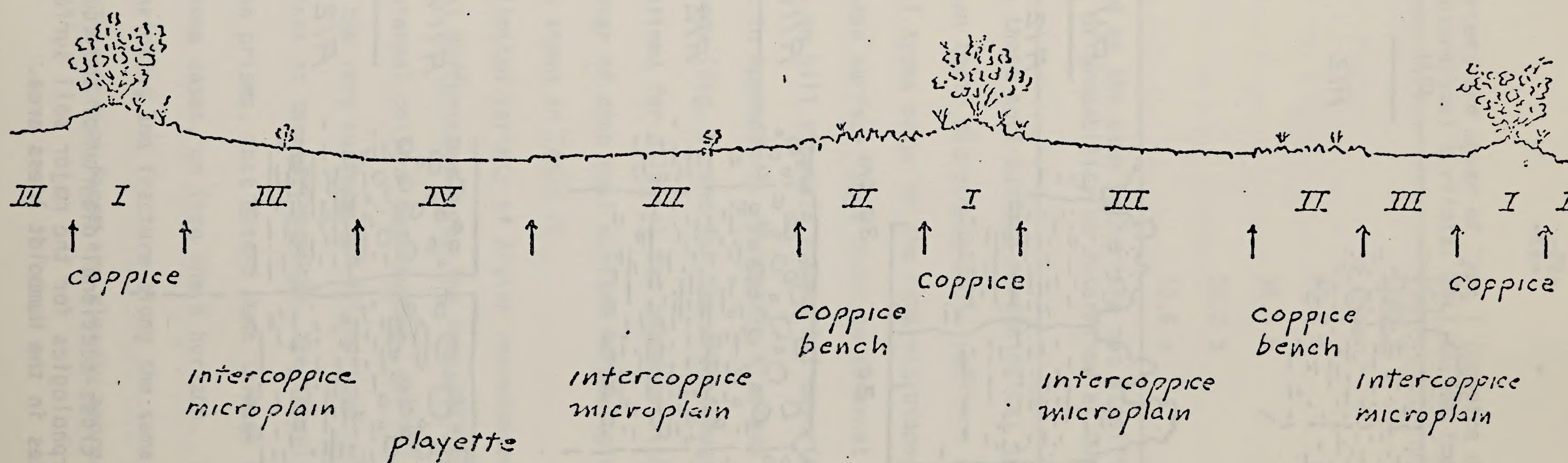

Figure 6. Schematic cross-sectional diagram of the microtopographic positions of the major soil surface morphological types at the seeding sites within the Humboldt loess area.

Table 9. Soil surface morphological types.

Soil Surface Morphological Type	Microtopographic Position	Description of Microtopographic Position
I	Coppice	A semi-conical form, the highest microtopographic elevation.
II	Coppice bench	A flattish, or gently sloping area next highest to the coppice, and higher than any adjacent intercoppice microplain or playette, if the latter occur.
III	Intercoppice microplain	A gently sloping or nearly flattish area next lower than the coppice bench. (Absent in some situations)
IV	Playette	A slightly depressional area or flat area at the lowest micro-topographic elevation and surrounded by coppice benches, or intercoppice microplains. (Absent in some situations).

or crust layer of Types II, III, and IV, but become more difficult to distinguish with depth through the A12 horizon, and especially any A2 horizon present. They are rather difficult to distinguish in a root-proliferated and litter covered Type I coppice soil.

Table 10. Proportionate coverage of soil surface morphological types at 1975-76 seeding sites.[1/]

Seeding Site	Surface Type I	II	III	IV
	- - - - - - - - -	% Cover	- - - - - - - -	
Lower Coils Creek	28.2 b[2/]	30.0 b	41.1 b	0.7 a
Upper Coils Creek	26.5 b	23.7 a	49.7 c	0.1 a
Panther Canyon	27.6 b	72.0 c	0.4 a	0.0 a
Paradise Valley	8.4 a	27.4 ab	63.6 d	0.6 a

1/ Based on 780 m of line transects spaced about 0.6 m apart in 7.8 m segments within 10 seeding plots at each site. The areas had been somewhat disturbed by shrub removal before the transects were read.

2/ Means followed by the same letter are not significantly different at the .05 level of probability as determined by Duncan's Multiple Range Test.

Type IV soil surfaces have flat, relatively very large polygons (roughly 20-36 cm diameter) with sharply angular crack shoulders. Most commonly, they are mazic[2/] but can be partially lichen covered in some area protected from trampling. At the study sites, they have little or no pavement nor pebble rings.

Type III surface soil surfaces have flat, moderately large polygons (roughly 13-26 cm diameter) with rounded crack shoulders forming very slightly trenched cracks. A few polygon cracks are bermed. Where small amounts of surficial gravel are present, the polygons have pebble rings and can be partially paved. The polygons are mazic or pustulose[3/], or can be partially or wholly lichen covered where protected from trampling.

Type II soil surfaces have pinnacled, micropinnacled, or convex, sometimes concave, relatively small polygons (roughly 7-15 cm diameter) with trenched cracks. Many are lichen covered, some are moss covered.

Type I soil surfaces have pinnacled or more commonly convex, small polygons (roughly 5-10 cm diameter) with round shouldered or trenched cracks most commonly filled with litter. Litter or moss and lichen cover most the surface.

Internal morphological features are fairly consistently correlated with external polygon features and microtopographic position. They must be used to confirm visual soil surface morphological identifications, or to decide identity where visible features are intermediate. The most distinctive internal morphological features of the polygons (i.e., squat prisms) occur in the very surface subhorizon, i.e., an A11v or A11 subhorizon.

In soil surface morphological Types III and IV this surficial A11v subhorizon (postscript v indicates vesicular) is a prominent, relatively thick

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2/ A mazic soil surface is defined here as a barren surface consisting of tightly packed, massive, uncoated silt and sand grains which lend a relatively smooth, whitish appearance.

3/ A pustulose surface is a mazic surface that is finely pitted and bumpy.

(4-8 cm) crust that is massive and coarsely vesicular (>1 mm diameter vesicles dominantly). The A12 subhorizon is distinguished from the A11v subdivision by the former's platyness. Where recently trampled, the upper 2 cm or so of the A11v is massive and lacks coarse vehicles, whereas the lower part retains its coarse vesicles. At any particular site, this massive, coarsely vesicular A11v subhorizon is thickest on Type IV surfaces (4-8 cm thick) and thinner on Type III surfaces (1.5-4 cm thick).

Type II soil surfaces and pinnacled Type I soil surfaces most commonly have no coarsely vesicular massive crust. If a crust occurs on a Type II surface it is <2 cm thick, only very slightly hard, and has suggestions of a weak, medium platyness. The A11 horizon here is distinguished by its fragility (i.e., very slightly hard) whether it is finely platy and subangular blocky, or nonvesicular-massive, or finely vesicular-massive. Delicate dissection can show surficial crust (at least 1-3 mm thick) but it is apt to be overlooked except on Type II surfaces without pinnacles (i.e., convex or concave polygons).

Type I surfaces consistently have a weak to moderate, very fine subangular blocky (<1 mm) structured A11 subhorizon if covered with litter, lichen, or moss.

Both the barren, undisturbed mineral soil surfaces and the crushed A11v subhorizons of Type IV surfaces are lightest in value and lowest in chroma (e.g., 6-7/2-3 dry, 4/2-3 moist, crushed) of all the types. The undisturbed Type III mineral soil surfaces commonly are slightly darker than the Type IV and lighter than the Type II. Barren Type II surfaces commonly have slightly higher chroma than Type III, and are noticeably darker and higher chroma than Type IV surfaces. Type I surfaces have the darkest colored A11 horizons (e.g., 4-5/1-2 dry, 3-4/1-2 moist, crushed).

Size and Shape of Areas of Soil Surface Morphological Types

Type I surfaces on coppices almost always support big sagebrush at the study sites and are somewhat larger than the shrub canopy. They are semicircular (0.2-1.0 m diameter) under single shrubs, or form lobate or beaded areas up to several meters long where shrubs are closely spaced.

Type II surfaces on coppice benches most commonly form 0.3-1.5 m wide, discontinuous, lobate margins alongside coppices. In some cases, they are irregularly lobate, 0.5-3 m wide areas without an adjacent coppice, but trunks of dead big sagebrush occur on most such areas. At one seeding site (Panther Canyon) the Type II surface forms an almost continuous matrix area for closely spaced coppices, i.e., there is very little Type III or IV surface. During heavy rains or snowmelt periods, water does not stand on, and is seldom seen running across Type I or II surfaces.

Type III surfaces on intercoppice microplains are probably the most extensive surface type for most Aridisols. They form continuous, gentle, roughly 0.2-5 m wide slopes between and around Type I and II surfaces on coppices and coppice benches. Frequently, the intercoppice microplain on which they occur are almost flat for a 0.3-2 m reach, and form indistinct steps similar to playettes. During heavy rainstorms and snowmelt, water runs over, and stands briefly on Type III surfaces. Where these surfaces are flattish, thin scums of ice can form at night during major snowmelts.

Type IV surfaces on playettes occur as semicircular or elongated flats or very shallow depressions 0.5-5 m wide. Water stands on them longest after moderate rainstorms or during snowmelt periods. Ice sheets up to several centimeters thick regularly form on them at night during snowmelt periods.

Vegetation Patterns

At the seeding sites studied, the Type I surfaces regularly support big sagebrush; occasionally the shrub is dead but the coppice is till intact. Bunchgrass may or may not occur under or to the side of the shrubs, depending on range condition. The interior of the coppice is commonly at least partially litter covered, otherwise mostly moss and lichen covered. Coppice margins commonly show bare soil and prominent pinnacling with Sandberg blue grass on top of some pinnacles.

The Type II surfaces are poorly vegetated, except at the Panther Canyon site. Sandberg bluegrass bunches are pedestaled (i.e., on a pinnacle) and occur near a polygon trenched crack, if not in it. Cheatgrass grows out of the trenched cracks and commonly covers the small polygons with litter. Seedling big sagebrush plants also occur in the trenched cracks, as do a few phlox plants. At some sites very well protected from trampling, lichen covers the entire Type II surface.

The Type III surfaces are mostly barren. Phlox and seedling big sagebrush grow from the slightly trenched or rounded cracks and a very few Sandberg bluegrass or squirreltail plants grow in or beside cracks. At some sites very well protected from trampling, lichen can cover the entire Type III surface.

Type IV surfaces are almost invariably barren except for partial lichen cover around polygon margins at some sites long protected from trampling.

Soil Surface Morphological Type Genesis

From site to site on different kinds of soils, the areal proportions of soil surface morphological types and the degree of crust expression for the surface types--particularly Type III surface--apparently varies with microtopographic position, kind of soil materials, and probably kind of

profile and climate. We have substantial field evidence from which genetic mechanism and sequence can be postulated for the Humboldt loess area where the seeding sites are located.

Genesis of Type IV and II Soil Surfaces

Massive vesicular crusting results from recurrent saturation then dessication of readily slaked,silty soil material. For a particular soil site, surficial saturation depends on water infiltrating more rapidly than it percolates down and out of the surficial subhorizon. Microtopographic positions that receive runoff in addition to precipitation and pond, or can only slowly dispose of surface runoff (i.e., playettes and intercoppice microplains) have the highest potential for surficial saturation. We find the thickest massive vesicular crusts on playettes, thinner ones on intercoppice microplains, and little or no such crusting on coppice benches or coppices.

Given rapid enough water addition to pond or sheet-flood, soil hydraulic conductivity determines the rate and depth of soil saturation. Slaking very fine sandy loams and silt loams probably have such a critically low hydraulic conductivity, in addition to those capillary properties necessary for vesicle formation and perhaps platy structure formation. (The exception paucity of Type III and IV surfaces on the Panther Canyon silt loam soils might be due to a particularly pervious and thick A horizon).

Two other morphologival features probably abet low A horizon hydraulic conductivity to cause surficial saturation. Water percolating by unsaturated flow is markedly retarded when it passes from a finely porous layer to a more coarsely porous layer. The prominent fine platy structure of the A12 subhorizons, in the soils studied, interjects coarse horizontal pores below the surficial A11 subhorizon and might tip the scales for sufficiently low water tension in the A11 horizon to cause vesicular crusting.

Water penetration is also retarded by underlying, slowly pervious argillic or natric horizons. During major storms and snowmelt, enough water is added tó many Aridisols--particularly in the playette position--to fill the A horizon if it cannot percolate through the argillic or natric horizon. After storms on dry soils, some Type IV playette surfaces are temporarily and shallowly ponded and saturated down to, and a centimeter or so past, a shallow (10-15 cm) abrupt textural boundary to a clayey argillic or natric horizon. Adjacent Type III, II, and I surfaces on thicker A horizons are more deeply wetted and neither saturated nor ponded. In some soil landscapes or eastern Washington, Oregon, and southern Idaho, massive vesicular soil surfaces are coincident with small spots of Natrixerolls or Natrargids in a matrix of Haploxerolls. In southern Idaho, Type IV playette surfaces are coincident with spots of thinner A horizons on continuous Nadurargids. At our study sites, shallow argillic or natric horizons might determine location of some, but probably not all, Type IV playette surfaces.

Genesis of Types I and II Soil Surfaces

Type I coppice surfaces are the apparent result of accumulation of windblown soil material at the base of a shrub that sprouted in a Type II or III surface. Concurrent incorporation of litter and root residues lead to higher humus contents and formation of moderate very fine subangular blocky structure. Primary evidence for coppice dune aeolian accumulation is continuity of the relatively light colored A11v subhorizon of contiguous Type III surfaces horizontally under the slightly higher, dark colored, semiconical A11 horizon of a coppice. The coppice A11 horizon commonly is slightly sandier than an adjacent Type III A11 horizon, and than the buried, apparent lateral extension of adjacent A11v subhorizon. Where buried under a coppice, this former soil surface horizon apparently acquires the prominent compound fine platy and very fine subangular blocky structure

that is characteristic of the continuous A12 horizon under all four surface types. Thus, under a coppice the A12 appears slightly thicker with a slightly lighter grey color in its upper 4-6 cm (i.e., the presumably buried former surficial horizon) than away from the coppice. Occurrence of big sagebrush seedlings in polygon cracks of Type II or III surfaces, without coppice dunes, somewhat larger shrubs with small coppice dunes, and large old shrubs with relatively high coppice dunes are accessory evidence of aeolian accumulation around shrubs initially started in Type II and III surfaces.

The margins of Type I coppices are prominently pinnacled where not litter covered and some are barren and appear eroded as well as pinnacled. Where sagebrush have died recently, litter cover is absent and yet the semiconical coppice dune is strongly pinnacled, frequently mostly bare, and give the impression of being eroded. Where only a few trampled down, centripedally strewn fragments of a dead sagebrush occur on a Type II pinnacled surface, there is no longer a semiconical peak, or dune-coppice form at the site of the shrub crown. This apparent sequence suggests Type II surfaces are the flattened and pinnacled remnants of former coppice dunes.

Trampling Effects

Cow trampling, particularly along traffic paths between shrub coppices, disrupts the A11 subhorizons of the various surface types. It is least disruptive on Type I coppices, since the animals seldom step into a shrub coppice, and on the Type IV playettes, since surficial mixing little alters the already very inhospitable soil environment.

Trampling Type II coppice benches and Type III intercoppice microplains-- both located in the major traffic routes-- destroys trenched cracks, A11 subhorizon structure, surface roughness (pinnacles), and stabilizing lichen and

moss cover. The powdered soil material is liable to wind or water erosion. When Type III surface soil rewets, it initially slakes to a slightly hard, or hard, massive microporous crust that our greenhouse trials suggest is a very poor seedbed. Type II A11 material doesn't seem to slake to as hard a crust, and seems to develop platyness more rapidly than Type III material on repeated wetting-drying. Field observations suggest the degree of crusting and rate of surface morphology reformation depends both on the original type soil surface trampled, and on the texture and humus content of the A11 subhorizon soil material -- perhaps the entire epipedon and profile -- at any particular site (i.e., kind of soil at the soil series or phase level).

Morphological Sequence of Surface Reformation

Cow trampling disrupts and powders the A11 horizons of all surface types. Each appears to reform in time if its microtopographic position hasn't been obliterated. In all cases, the powdered A11 subhorizon appears to slake to a massive, nonvesicular crust with relatively large, flat, incomplete, angular-shouldered polygons on first or first several wettings. After trampling, Type IV surface material reforms its coarse vesicles, and is then as it was. Type III surface material appears to regain coarse vesicularity and rounded or slightly trenched cracks and is recompleted. Type II material appears to first form rounded cracks and marginal micropinnacles on the polygons, then trenched cracks and full pinnacles. Its initially massive nonvesicular surface becomes platy and friable. Where trampling destroys the shrubs on Type I coppice, they probably convert to Type II surfaces.

METHODS

1974-75 Seeding

A portion of each exclosure was divided into forty 6X6 m subplots. Twenty subplots were deep plowed and 20 were not plowed. In both treatments, four seeding techniques were used in fall, 1974: 1) seed to simulate a standard rangeland drill, 2) seed to simulate a deep-furrow rangeland drill, 3) broadcast with simulated cow trampling, 4) broadcast without simulated cow trampling. Four species were evaluated: 1) squirreltail, 2) Thurber needlegrass (Stipa thurberiana) 3) crested wheatgrass, and 4) fourwing saltbush (Atriplex canescens). Seeding rate for grasses was one seed/1.27 cm of row in drill treatments and 5 seeds/120 sq cm in the broadcast-simulated cow trampling treatment. Twenty grass seeds or 10 fourwing saltbush seeds/920 sq cm were planted in the broadcast-no simulated cow trampling treatment. Each treatment was replicated five times. Seedling counts were made in the spring and summer of 1975 on coppice and interspace soils and converted to percent emergence based on number of seeds planted. In fall, 1976, the frequency of established plants/30 cm (1 ft.) of row was determined for the coppice and interspace soils at each location. Crown cover of established fourwing saltbush plants was measured and converted to square meters of shrub crown.

1975-76 Seeding

Seeding treatments and species were the same as those used in 1974-75 except that only the unplowed treatment was evaluated. Prior to seeding in fall, 1975, the proportion of each seeded row or broadcast microplot was classified according to the type of soil surface morphology. In June, 1976, seedling counts were made on each surface type and numbers converted to percent

emergence. In fall, 1976, the frequency of established plants of each species on each surface type was determined at the Lower and Upper Coils Creek sites. At the lower site, frequency was determined on the standard-and deep-furrow seeding treatments. At the Upper site, only the deep-furrow site was evaluated. The standard-drill treatment at the Upper site and both seeding treatments at Panther Canyon and Paradise Valley were not evaluated because of invasion of native species, and dense stands of fall germinated seedlings of species planted the previous fall and not germinated in the spring due to drought conditions.

RESULTS AND DISCUSSION

1974-75 Seeding

Results of site preparation, species, seeding method, and soil treatments are given in tables 11-14. The interactions of these treatments are found in Appendices III-VI.

Plowing the soil did not increase grass emergence at any site (Table 11). In fact, plowing reduced emergence at Upper Coils Creek and Paradise Valley. Following plowing, coppice dune and dune interspace areas were indistinguishable. The surface soil tended to reform to a massive, vesicular crust over the entire plowed area and impede emergence.

Overall species emergence was best at Upper Coils Creek. Crested wheatgrass had the highest emergence at all sites (Table 12), and Thurber needlegrass had the lowest emergence. Emergence of squirreltail was lower than for crested wheatgrass but higher than for Thurber needlegrass.

The deep-furrow drill treatment gave the highest emergence for all species in plowed and unplowed soils at Lower and Upper Coils Creek (Table 13). The standard-drill treatment gave the highest emergence at Paradise Valley, probably because disturbance of the surface soil was less with this treatment than with

Table 11. Mean percent emergence of all grass species in plowed and unplowed soil at each seeding trial site.

Site	Treatment	Percent Emergence1/
Lower Coils Creek	plowed	7.3a
	unplowed	6.9a
Upper Coils Creek	plowed	13.7a
	unplowed	17.9b
Panther Canyon	plowed	10.5a
	unplowed	8.3a
Paradise Valley	plowed	5.7a
	unplowed	12.3b

1/ Means followed by the same letter are not significantly different at the .05 level of probability as determined by Duncan's Multiple Range Test.

Table 12. Mean percent emergence of crested wheatgrass, squirreltail, and Thurber needlegrass at each seeding trial site.

Site	Species	Percent Emergence[1/]
Lower Coils Creek	crested wheatgrass	11.2c
	squirreltail	7.2b
	Thurber needlegrass	3.0a
Upper Coils Creek	crested wheatgrass	17.8c
	squirreltail	14.5b
	Thurber needlegrass	10.1a
Panther Canyon	crested wheatgrass	14.1c
	squirreltail	9.9b
	Thurber needlegrass	5.3a
Paradise Valley	crested wheatgrass	13.9c
	squirreltail	11.0b
	Thurber needlegrass	2.1a

1/ Means followed by the same letter are not significantly different at the .05 level of probability as determined by Duncan's Multiple Range Test.

Table 13. Mean percent emergence of all grass species seeded by the standard drill, deep-furrow drill, broadcast-simulated cow trampling, and broadcast-no simulated cow trampling techniques at each site.

Site	Treatment	Percent Emergence[1/]
Lower Coils Creek	standard drill	10.7c
	deep-furrow drill	14.3d
	broadcast-simulated cow trampling	3.0b
	broadcast-no simulated cow trampling	0.4a
Upper Coils Creek	standard drill	15.3b
	deep-furrow drill	21.4c
	broadcast-simulated cow trampling	17.1b
	broadcast-no simulated cow trampling	2.8a
Panther Canyon	standard drill	8.8b
	deep-furrow drill	11.1b
	broadcast-simulated cow trampling	15.1c
	broadcast-no simulated cow trampling	2.7a
Paradise Valley	standard drill	18.3c
	deep-furrow drill	12.1b
	broadcast-simulated cow trampling	3.7a
	broadcast-no simulated cow trampling	1.8a

1/ Means within location followed by the same letter are not significantly different at the .05 level of probability as determined by Duncan's Multiple Range Test.

deep furrows. Emergence on the broadcast-simulated cow trampling treatment was third highest except at Panther Canyon where it was the best treatment. Broadcast-no simulated cow trampling gave the lowest emergence at all sites.

Emergence of all species at all sites was significantly higher in coppice soil than in interspace soil (Table 14). This was the same result as obtained in the greenhouse studies, although soil disturbance was less in field studies.

At Lower Coils Creek, seedling emergence in unplowed and plowed soil was similar. The deep-furrow treatment gave the highest emergence for all species. Standard drill was second highest but was not significantly different from deep furrows. Emergence in the broadcast-simulated cow trampling treatment was less than in the drill treatments. The broadcast-no simulated cow trampling treatment virtually failed. Significantly more seedlings emerged in the coppice than in the interspace soil. Crested wheatgrass in deep furrows in coppice soil had the best emergence. Highest emergence of all species was in deep furrows, but this treatment was not significantly better than the standard drill except with crested wheatgrass in the coppice soil. Emergence of crested wheatgrass was higher than squirreltail, and squirreltail was higher than Thurber needlegrass in both coppice and interspace. In the coppice soil, emergence of crested wheatgrass and squirreltail was not significantly different nor was emergence of squirreltail and Thurber needlegrass. In the interspace soil, emergence of all species was equally poor.

At Upper Coils Creek, emergence was significantly greater in unplowed soil than in plowed soil. Deep furrows gave the highest emergence for all species except for Thurber needlegrass in the unplowed soil. In plowed soil, both drill treatments gave similar results. Emergence was similar in the broadcast-simulated cow trampling, deep furrow, and standard drill treatments. Broadcast-no simulated cow trampling was significantly lower than all other

Table 14. Mean percent emergence of crested wheatgrass, squirreltail, and Thurber needlegrass on Type I and Type III surface soils at the four study sites.

Location and Species	Percent Emergence[1/]	
	Type I (Coppice)	Type III (Interspace)
Lower Coils Creek		
Crested wheatgrass	14.3[a]	5.8[c]
Squirreltail	10.5[b]	3.1[d]
Thurber needlegrass	6.0[c]	1.5[d]
Upper Coils Creek		
Crested wheatgrass	22.5[a]	11.5[b]
Squirreltail	25.1[a]	9.8[b]
Thurber needlegrass	14.4[b]	10.9[b]
Panther Canyon		
Crested wheatgrass	15.6[a]	3.0[cd]
Squirreltail	11.1[b]	5.0[cd]
Thurber needlegrass	6.6[c]	1.8[d]
Paradise Valley		
Crested wheatgrass	22.7[a]	11.7[b]
Squirreltail	21.4[a]	11.6[b]
Thurber needlegrass	5.0[c]	1.2[c]

1/ Means within location followed by the same letter are not significantly different at the .05 level of probability as determined by Duncan's Multiple Range Test.

treatments. More seedlings emerged in the coppice than in the interspace soil. Emergence of crested wheatgrass was lower than squirreltail in the coppice soil and higher than squirreltail in the interspace. Emergence of both these species was significantly higher than Thurber needlegrass in the coppice soil. Thurber needlegrass emergence was higher than for squirreltail in the interspace but lower than for crested wheatgrass. Crested wheatgrass in deep furrows in coppice soil had the highest emergence. The standard drill, deep-furrow drill, and broadcast-simulated cow trampling treatments all gave similar results. Highest emergence in interspace soil was by Thurber needlegrass broadcast with simulated cow trampling.

At Panther Canyon, emergence in unplowed and plowed soil was similar. Highest emergence in unplowed soil was on the broadcast-simulated cow trampling and deep-furrow treatments. Best emergence on plowed soil was on the broadcast-simulated cow trampling treatment. Emergence in the standard-drill treatment was significantly lower than with broadcast-simulated cow trampling and similar to deep furrows. The broadcast-no simulated cow trampling treatment gave the poorest results. More seedlings emerged in the coppice than in the interspace soil. In coppice soil, emergence of crested wheatgrass was higher than squirreltail, and squirreltail was higher than Thurber needlegrass. The same relationship existed in interspace soil. Squirreltail and Thurber needlegrass emergence in coppice soil was not significantly different from the interspace.

Highest emergence was by crested wheatgrass in deep furrows in coppice soil. For all species, emergence was highest with broadcast-simulated cow trampling and in deep furrows. Standard drill was significantly lower than broadcast-simulated cow trampling and deep-furrow treatments, and significantly higher than broadcast-no simulated cow trampling. In the interspace soil, broadcast-simulated cow trampling gave the highest emergence.

At Paradise Valley emergence was significantly higher in unplowed soil than in plowed soil. In both plowed and unplowed soil, the standard-drill technique gave the greatest emergence. Emergence in deep furrows, particularly in plowed soil, was reduced because soil slaked when saturated, furrows ran together, and seeds and seedlings were buried too deep to emerge. Broadcast-simulated cow trampling rated third in success. Brodcast-no simulated cow trampling completely failed. More seedlings emerged in the coppice than in the interspace. Emergence of crested wheatgrass was not higher than squirreltail, but both species emerged better than did Thurber needlegrass. Emergence of Thurber needlegrass was similar in coppice and interspace soils.

The deep-furrow treatment gave greater emergence than the broadcast-simulated cow trampling treatment and broadcast-no simulated cow trampling. In the standard-drill treatment, emergence of crested wheatgrass and squirreltail was similar in the coppice and interspace soils. The same species relationship existed in both broadcast treatments and in deep furrows.

Fourwing Saltbush Stand

Fourwing saltbush failed or almost failed to produce a stand at all sites when broadcast without simulated cow trampling (Table 15). The best stand was at Lower Coils Creek in the drill treatments. This was followed closely by the drill treatments in unplowed soil at Upper Coils Creek, and by the drill treatments at Panther Canyon in plowed soil. Essentially all treatments failed at Paradise Valley. The broadcast-simulated cow trampling treatment failed except in the unplowed soil at Upper Coils Creek and in the plowed area at Panther Canyon.

Table 15. Mean distance between fourwing saltbush plants for the various treatments in both unplowed and plowed treatments at the four sites.

Treatment and Seeding Method	Lower Coils Creek	Upper Coils Creek	Panther Canyon	Paradise Valley
	Mean distance between plants (meters)			
Unplowed				
standard drill	1.3	1.2	Infinity	Infinity
deep-furrow drill	.9	1.2	Infinity	Infinity
broadcast - simulated cow trampling	Infinity	33.6	121.2	Infinity
broadcast - no simulated cow trampling	2286.5	571.6	Infinity	Infinity
Plowed				
standard drill	1.5	54.9	1.4	1800
deep-furrow drill	1.0	8.4	1.3	900
broadcast - simulated cow trampling	143.0	Infinity	26.0	Infinity
broadcast - no simulated cow trampling	571.6	Infinity	1143.3	Infinity

The long-term value of a species or seeding treatment is expressed by the stand density of established plants. Frequency of occurrence per 30 cm (1 ft.) of seeded row was used to estimate stand density. Percent frequency was determined for the site preparation, species, seeding method, and soil variables and for treatment interactions (Tables 16 and 17 and Appendices VII, VIII, and IX). A frequency of 100% would indicate at least one established plant per 30 cm of row. A frequency of 50% would indicate at least one established plant per 60 cm of row.

Examples of typical results are given for the Lower Coils Creek and Paradise Valley sites (Tables 16 and 17). Lower Coils Creek results were similar to those from Upper Coils Creek and Panther Canyon. Crested wheatgrass stands were superior to squirreltail stands at Upper Coils Creek and Panther Canyon in the unplowed treatment. Stands of both species were also significantly better in deep furrows than in the standard-drill treatment. One reason for this response is the reduction in perennial and annual grass competition by deep furrowing at Upper Coils Creek and Panther Canyon, respectively. The standard-drill treatment planted seed directly into the competition. Stands of the two species were similarly poor at Paradise Valley, and similarly good at Lower Coils Creek. Thurber needlegrass stands were generally poor in all treatments. Frequency of fourwing saltbush indicated a low plant density. However, growth of these plants in the second year, particularly in the plowed treatment at Coils Creek and Panther Canyon, created a stand with a good vegetative and forage composition of this shrub.

Data from Paradise Valley indicated generally poor stands of all species in both plowed and unplowed treatments. Stands of crested wheatgrass and squirreltail were similar in deep furrows, but crested wheatgrass was superior

Table 16. Mean percent frequency of established grass and shrub plants in 1976 on plowed and unplowed treatments on two study sites in relation to seeding technique. Plots were seeded in Fall, 1974.

Location and Species	Percent Frequency[1/] Plowed: Deep furrow Drill	Plowed: Standard Drill	Unplowed: Deep furrow Drill	Unplowed: Standard Drill
Lower Coils Creek				
Crested wheatgrass	91.6 j	88.6 j	70.5 o	66.9 o
Squirreltail	79.0 h-j	64.6 hi	60.8 no	62.7 no
Thurber needlegrass	28.0 d-f	23.0 c-f	42.9 j-m	47.5 lm
Fourwing saltbush	28.4 d-g	22.8 c-f	26.4 d-i	26.9 d-i
Paradise Valley				
Crested wheatgrass	32.4 e-g	66.4 hi	28.0 i-l	52.3 mn
Squirreltail	32.4 e-g	44.0 g	35.8 g-l	30.4 e-j
Thurber needlegrass	10.6 a-c	8.0 ab	16.0 b-e	2.2 a
Fourwing saltbush	0.4 a	0.2 a	0.0 a	0.0 a

1/ Frequency means in columns or between rows within the plowed or unplowed treatments with the same letters are not significantly different at the .05 probability level as determined by Duncan's Multiple Range Test.

Table 17. Mean percent frequency of established grass and shrub plants in 1976 on the unplowed treatment at two study sites in relation to Type I and Type III surface soils. Plots were seed in fall, 1974.

Location and Species	Percent of Frequency[1/] Type I (Coppice)	Type III (Interspace)
Lower Coils Creek		
Crested wheatgrass	75.1 o	62.3 l-o
Squirreltail	73.8 m-o	49.7 i-l
Thurber needlegrass	63.4 m-o	27.0 e-g
Fourwing saltbush	31.0 gh	24.3 d-g
Paradise Valley		
Crested wheatgrass	61.4 l-n	28.9 fg
Squirreltail	62.4 l-o	3.8 ab
Thurber needlegrass	17.1 c-f	1.1 ab
Fourwing saltbush	0.0 a	0.0 a

1/ Frequency means within rows or columns with the same letter are not significantly different at the .05 level of probability as determined by Duncan's Multiple Range Test.

in the standard-drill treatment. The general depressing effect of deep furrows on stand density was characteristic at Paradise Valley. The low frequency of crested wheatgrass and squirreltail in deep furrows was caused by furrows filling as the disturbed interspace surface became wet and unstable and slaked together. This problem was intensified by use of deep furrows on plowed soil. Conversely, the standard-drill treatment gave a better stand of crested wheatgrass in plowed soil compared with unplowed soil. In this instance, plowing controlled any competition present, mixed the lower A horizon material with a bit of the B horizon material with the vesicular horizon to produce a more favorable surface soil for seedling emergence, and the standard drill did not disturb the soil as much as did the deep-furrow treatment. In addition, even if some slaking did occur, depth of covering the seed and seedlings was not as great as with slaking of deep furrows.

Stands of the three grass species were significantly better on the coppice soil than on the interspace soil. On coppice soil, Thurber needlegrass plants were sparse without much herbage volume. Squirreltail stands were better and individual plants produced a good volume of herbage. Stands of crested wheatgrass were better than for the other two species. Best stands of all species were found at Lower Coils Creek. On interspace soil, stands of crested wheatgrass were better than stands of the other species at both Coils Creek Sites and at Paradise Valley. Squirreltail and Thurber needlegrass produces only fair to poor stands at Lower Coils Creek and essentially failed at the other sites.

The crown growth of established plants of fourwing saltbush seeded on the plowed treatment was greatest at Lower Coils Creek (0.32 m^2), less at Panther Canyon (0.18 m^2) and least at Upper Coils Creek (0.10 m^2) (Table 18). Within location, growth was greatest in the standard-drill treatment at Lower Coils Creek, and similar in the deep and standard-furrows at Upper Coils Creek

Table 18. Mean crown area (m^2) of established fourwing saltbush plants in response to seedbed treatment, method of seeding, and soil.

Seeding Method and Soil	Crown Area (m^2)1/			
	Plowed			Unplowed
	Lower Coils Creek	Upper Coils Creek	Panther Canyon	Lower Coils Creek
Deep-furrow drill	0.25 c	0.10 ab	0.19 bc	-
Standard-furrow drill	0.40 d	0.09 a	0.18 abc	-
Deep-furrow drill				
Coppice	-	-	-	0.05 b
Interspace	-	-	-	0.01 c
Standard-furrow drill				
Coppice	-	-	-	0.03 a
Interspace	-	-	-	0.01 a

1/ Mean crown area within plowed or unplowed treatment followed by the same letter is not significantly different at the .05 level of probability as determined by Duncan's Multiple Range Test.

and Panther Canyon. Very few fourwing saltbush plants survived at Paradise Valley. Crown growth was less on the unplowed treatment than on the plowed treatment. Survival was negligible on the unplowed treatment at all locations except Lower Coils Creek. At this location, growth was greater in the deep furrows than in standard furrows. In standard furrows, shrub cover was similar in coppice and interspace soil. In deep furrows, growth was greater on coppice soil than on interspace soil.

Percent frequency of established grass and shrub plants was also determined for the broadcast treatments (Table 19) and was based on the number of microplots with one or more established plants out of a total of nine microplots seeded. Fair to good stands of crested wheatgrass and squirreltail were obtained on all sites on the plowed treatment both with and without simulated cow trampling. Good seed coverage was obtained in plowed soil by simulated cow trampling. Even without simulated trampling, enough safe-sites were available in the rough microtopography to moderate the seedbed environment and allow germination, emergence, and establishment of a moderate number of plants. Stands of Thurber needlegrass and fourwing saltbush were poor.

On the unplowed treatment, some establishment of crested wheatgrass and squirreltail was obtained at Lower Coils Creek. Most of the established plants were on the coppice soil where some microrelief occurred. Thurber needlegrass and fourwing saltbush stands failed at all locations. Evidently, even with simulated trampling, seed coverage was not adequate for germination and emergence especially in interspace soil where seed would be planted directly in the vesicular crust. The coppice areas at Lower Coils Creek had little vegetation, while at Upper Coils Creek and Panther Canyon the coppice sites had good stands of perennial grass and cheatgrass, respectively. Establishment was greatly reduced on these sites due to competition. Establishment at Paradise Valley was low because the interspace soil surface type makes up a

Table 19. Percent established grass and shrub plants in broadcast treatments in plowed and unplowed soil at four study sites in 1976. Plots were seeded in Fall, 1974.

Treatment and Species	Percent Frequency[1/] Location: Lower Coils Creek	Upper Coils Creek	Panther Canyon	Paradise Valley
Plowed				
Broadcast-simulated cow trampling				
Crested wheatgrass	33	58	30	36
Squirreltail	22	82	47	31
Thurber needlegrass	3	20	0	0
Fourwing saltbush	6	7	0	0
Broadcast-no simulated cow trampling				
Crested wheatgrass	44	51	24	38
Squirreltail	24	62	31	27
Thurber needlegrass	13	11	0	4
Fourwing saltbush	17	4	13	0
Unplowed				
Broadcast-simulated cow trampling				
Crested wheatgrass	17	0	0	11
Squirreltail	44	8	2	2
Thurber needlegrass	0	0	0	0
Fourwing saltbush	0	0	0	0
Broadcast-no simulated cow trampling				
Crested wheatgrass	19	0	2	16
Squirreltail	33	2	4	0
Thurber needlegrass	0	0	0	0
Fourwing saltbush	4	0	2	0

1/ Frequency of established plants is based on the number of microplots with one or more surviving plants of the nine microplots seeded per treatment.

large proportion of the surface and most microplots fell on this soil.

1975-76 Seeding

Species emergence on all sites in response to soil surface type and seeding method is presented in Appendix X. An example of the response at Paradise Valley is given in Table 20.

Mean emergence in spring, 1976 (4.0%) was much lower than in the previous year (10.5%). This response was probably due to much lower winter-spring precipitation in 1975-76 (11.3 cm) than in 1974-75 (20.4 cm). Emergence of crested wheatgrass (7.7%) and squirreltail (6.4%) was similar and was significantly higher than for Thurber needlegrass (0.9%). Highest emergence was found on the Type I (6.1%) and Type II (5.1%) surfaces. Lowest emergence was on the Type III (3.7%) surface. No seedlings emerged on the Type IV surface. Emergence on Type I and II surfaces was similar on all sites. On all three surfaces, emergence was significantly greater in deep furrows (7.1%) than in standard furrows (2.9%). In addition, crested wheatgrass and squirreltail emergence was enhanced by deep furrows on all sites while Thurber needlegrass responded favorably to deep furrows only at Upper Coils Creek. The favorable response to deep furrows was evident on Type I and II surfaces at all locations. Furrowing on Type III surface increased emergence at Upper Coils Creek and Paradise Valley. The response to deep furrows on Type III soil at Paradise Valley was different from that of 1975. In 1975, furrowing a soil with a vesicular crust, such as a Type III, resulted in soil slaking and furrows running together. This did not happen in 1976 because winter and spring precipitation did not saturate the soil and cause slaking. Therefore furrows maintained their integrity to provide a favorable microclimate for seedling emergence.

No seedlings emerged on the broadcast-simulated cow trampling treatment.

Table 20. Mean percent emergence of three grass species in Spring, 1976 on unplowed treatment at Paradise Valley in relation to soil surface type and seeding method. Plots were seeded in Fall, 1975.

Soil Surface Type 1/	Species	Seeding Method 2/	Percent Emergence 3/
I Coppice	Crested wheatgrass	SFD	3.8 a-c
		DFD	6.9 cd
	Squirreltail	SFD	1.6 ab
		DFD	11.3 de
	Thurber needlegrass	SFD	0.0 a
		DFD	0.4 a
II Coppice Bench	Crested wheatgrass	SFD	2.6 ab
		DFD	12.0 e
	Squirreltail	SFD	2.0 ab
		DFD	7.9 c-e
	Thurber needlegrass	SFD	0.0 a
		DFD	0.2 a
III Interspace Macroplain (Interspace)	Crested wheatgrass	SFD	1.1 ab
		DFD	10.8 de
	Squirreltail	SFD	1.1 ab
		DFD	4.7 bc
	Thurber needlegrass	SFD	0.0 a
		DFD	0.8 a

1/ Soil surface types are as described in Appendix I

2/ SFD = Standard-furrow drill; DFD = Deep-furrow drill.

3/ Percent emergence followed by the same letters are not significantly different at the .05 level of probability as determined by Duncan's Multiple Range Test.

The frequency of established plants from the 1975 seeding was determined on the standard-and-deep furrow treatments at Lower Coils Creek (Table 21) and on the deep-furrow treatment only at Upper Coils Creek. Only very few plants of fourwing saltbush survived at either location.

At Lower Coils Creek, the stand of established crested wheatgrass was superior to that of squirreltail and squirreltail was superior to Thurber needlegrass. Both crested wheatgrass and squirreltail stands were better in Type I (71.6%) and II (67.4%) soils than in Type III (40.4%) soil. The Thurber needlegrass stand was similar in all three soils in the standard furrows, but was superior in Type I soil (15.0%) compared with Type III soil (0.0%) in the deep furrows. Stands of crested wheatgrass and squirreltail generally were similar in standard and deep furrows except that the crested wheatgrass stand was improved in Type II soil by seeding in deep furrows (84.2%) compared with standard furrows (66.2).

At Upper Coils Creek in the deep-furrow treatments the stand of established plants of crested wheatgrass (58.9%) was best, followed by squirreltail (48.5%), and Thurber needlegrass (29.9%). Stands of Thurber needlegrass were generally better on soil Types I (50.6%) and II (30.6%) than on Type III (8.4%). Seeding on Type I and II soils produced better stands of crested wheatgrass (73.3%) and squirreltail (60.1%) than did seeding on Type III soil (30.2% and 25.2%, respectively).

In summary, seedbed preparation by plowing did not enhance emergence. Plowing decreased emergence on two sites because the high silt soil slaked when wet to form a very hard surface crust. Emergence and establishment of grasses on relatively high organic matter, low bulk density, and structured non-crusting Type I and II soil surfaces was always greater than on the

Table 21. Mean percent frequency of established grass plants in 1976 on the unplowed treatment at Lower Coils Creek in relation to seeding method, species, and surface soil type. Plots were seeded in Fall, 1975.

	Percent Frequency 1/					
Species	Standard Furrow			Deep Furrow Drill		
	Soil Surface Type			Soil Surface Type		
	I	II	III	I	II	III
Crested wheatgrass	83.2 h	84.2 h	46.0 ef	72.6 gh	66.2 g	48.8 e
Squirreltail	61.0 gh	62.6 gh	26.6 cd	69.4 gh	56.6 fg	40.2 de
Thurber needlegrass	0.0 a	1.6 a	0.0 a	15.0 bc	6.4 ab	0.0 a

1/ Frequency means within and between seeding method with the same letter are not significantly different at the .05 level of probability as determined by Duncan's Multiple Range Test.

crusted Type III and IV surfaces. Emergence and establishment of crested wheatgrass were generally better than for squirreltail and both species were superior to Thurber needlegrass. Emergence and establishment were best when seeded by the deep-furrow technique except on soils with a tendency to form hard crusts. On these soils, the standard-drill technique was superior. Both broadcast treatments gave very poor results or failed to produce a stand. Emergence and establishment of fourwing saltbush were much better in both drill treatments in plowed and unplowed soil than the broadcast treatments. Second-year crown growth of four-wing saltbush was best in plowed soil in both deep and standard furrows than in unplowed soil.

IMPACTS OF OFF-ROAD VEHICLE TRAFFIC

METHODS

The impacts of off-road vehicle traffic on infiltration and sediment production characteristics of soil were evaluated on two sites in southern Nevada. The Blue Diamond site is located about 7 km southwest of Las Vegas and the Crystal Springs site is some 62 km north of Las Vegas near Hiko (Fig. 1).

Shrub crown cover and the proportionate coverage of the various soil surface types (Types I, V, VI, and VII) were determined by the line intercept method.

Off-road vehicle treatments were imposed three times at each location: initiated in January, 1975, August, 1975, and January, 1976. Five treatments were used in the January, 1975 trial: single motorcycle pass, multiple motorcycle pass (50), single truck, and multiple truck pass (20) and a control. In the other two trials, only multiple-motorcycle and multiple-truck treatments and the control were evaluated since the single-!ass treatments gave results similar to the control. Motorcycles used in the study were trail-type bikes and the truck was a 4-wheel drive 3/4 ton pickup with 500 gallons of water in the bed. Vehicles were run over the terrain at about 32 km/hr and generally "hotrodding". Vehicle tracks were made in a straight line so that both coppice and interspace soil surfaces were disturbed. Five runoff plots (22.50 x 61.25 cm) were placed in both the coppice and interspace soil type in each traffic treatment and in the control. Shrubs were removed from the coppice areas by cutting at ground level. Sheet metal plot frames were inserted into the soil with minimal disturbance. Simulated precipitation was applied at a rate of 3.38 cm/hr for 30 minutes in the other two trials. Application of 7.50

cm/hr for 30 minutes represents a precipitation rate in excess of a 100-year recurrence interval at both sites. Application of 3.38 cm/hr for 30 minutes represents a precipitation rate with a recurrence interval of between 2 and 50 years at Blue Diamond and of about 50 years at Crystal Springs. Runoff was measured every 5 minutes for 30 minutes and sediment was collected after 30 minutes. Five minute and terminal infiltration in cm/hr were calculated from the runoff data and sediment was expressed in kg/ha. Runoff and sediment data were collected only once in the January, 1975 trial. In the other two trials, plots were covered with plastic and the soil surface crust allowed to dry and reform. This process took less than a month during the hot part of the year to several months during the cool part of the year. After crust reformation, simulated precipitation was applied again to the same plots at the same rate as before and runoff and sediment data were collected.

Damage of shrubs in the motorcycle and truck tracks was estimated in October, 1976 for all three trials.

RESULTS AND DISCUSSION

Total shrub cover at Crystal Springs is 25.2% with blackbrush (Coleogne ramosissimum) the most important species (Table 22). Soil is a loamy-skeletal, mixed, thermic, shallow, Typic Durothid. Characteristics of the soil profile and of the three soil surface types are presented in Appendix I. Due to the high shrub cover, the proportionate coverage of the Type I and VII surfaces are high (34.7%) as is the Type VI or gravel mulch surface (49.3%). The strong vesicular crust with imbedded pavement (Type V) represented only 16.0% of the area (Table 22). At Blue Diamond, total shrub crown cover is only 8.3% with spiney hopsage (Grayia spinosa) and white bursage (Ambrosia damosa) the most important species (Table 22). Soil is described as a loamy-skeletal, carbonatic, thermic, shallow, Typic Paleorthid.

Table 22. Percent shrub crown cover and percent area of soil surface types at the two off-road vehicles sites.

	Shrub Cover - %	
Species	Blue Diamond	Crystal Springs
Spiney hopsage	3.9	-
White bur sage	2.8	-
Creosote bush	0.2	-
Range ratany	0.2	-
Joint fir	0.4	1.4
Box thorn	0.8	2.0
Blackbrush	-	21.8
	Soil Surface Type Area - %	
Soil Type		
I and VII	14.2	34.7
V	67.8	16.0
VI	18.0	49.3

Characteristics of the soil profile and of the soil surface at this location are presented in Appendix I. Cover of Types I and VII soil surfaces (14.2%) on coppices is somewhat greater than the actual shrub crown cover (Table 22). The Type V surface (67.8%) made up the greatest proportion of soil surface cover and is the major surface type in the interspaces between widely spaced shrubs.

Infiltration - January, 1975

Infiltration rates in this trial were higher at Crystal Springs than at Blue Diamond; were reduced by multiple-motorcycle and multiple-truck treatments; and were less on interspace soils than on coppice soils (Table 23). The higher infiltration values in this trial than in the later trials was due to a higher water application rate and the possibility of more depression storage on the uneven soil surface of the infiltration plots.

Locations responded differently to imposed variables. At Blue Diamond and Crystal Springs the infiltration capacity of the interspace soils was 37 and 18% of the coppice capacity, respectively. At Blue Diamond both multiple-traffic treatments reduced infiltration. At Crystal Springs, the multiple-traffic treatments were similar to the control. Overall, multiple traffic reduced infiltration of the coppice soil by an average of 2.34 cm/hr. This effect was most pronounced at Blue Diamond where the multiple-vehicle treatments reduced infiltration of the coppice soil by 3.20 cm/hr (Table 24). This trend was similar at Crystal Springs except that a significant difference occurred only between the control and multiple-motorcycle treatments. Infiltration of the interspace soil was similar on all treatements at Blue Diamond. Conversely, at Crystal Springs, the multiple-vehicle treatments appeared to increase the infiltration capacity of the interspace soil (Table 24).

Table 23. Mean terminal infiltration rate (cm/hr) in response to imposed variables. Simulated precipitation was applied at the rate of 7.50 cm/hr for 30 minutes in the initial 1975 trial and at 3.38 cm/hr for 30 minutes in the following trials.

Variable	Terminal Infiltration		
Study Site	Jan, 1975	Aug, 1975	Jan, 1976
Crystal Springs	4.49 b	1.73 a	1.46 a
Blue Diamond	3.28 a	1.90 a	1.37 a
Soil			
Interspace (Types V & VI)	2.34 a	0.94 a	0.23 a
Coppice (Types I & VII)	5.43 b	2.68 b	2.60 b
Run			
First	-	2.17 a	1.53 a
Second	-	1.46 b	1.30 b
Vehicle Treatment			
multiple motorcycle	3.68 a	1.52 a	1.36 a
multiple truck	3.54 a	1.60 a	1.15 a
control	4.44 b	2.23 b	1.74 b

1/ Means within year followed by the same letter are not significantly different at the .05 level of probability as determined by Duncan's Multiple Range Test.

Table 24. Terminal infiltration at the two study sites in response to treatment and soil in January, 1975 trial. Simulated precipitation was applied at the rate of 7.50 cm/hr for 30 minutes.

Treatment and Soil	Location	
	Blue Diamond	Crystal Springs
	Terminal Infiltration (cm/hr)[1/]	
Control		
Interspace (Types V and VI)	1.80 a	2.02 a
Coppice (Types I and VII)	6.90 c	7.03 d
Multiple Motorcycle		
Interspace (Types V and VI)	2.23 ab	3.44 b
Coppice (Types I and VII)	3.70 b	4.81 c
Multiple Truck		
Interspace (Types V and VI)	1.30 a	3.82 bc
Coppice (Types I and VII)	3.76 b	6.37 d

[1/] Means within location followed by the same letter are not significantly different at the 0.5 level of probability as determined by Duncan's Multiple Range Test.

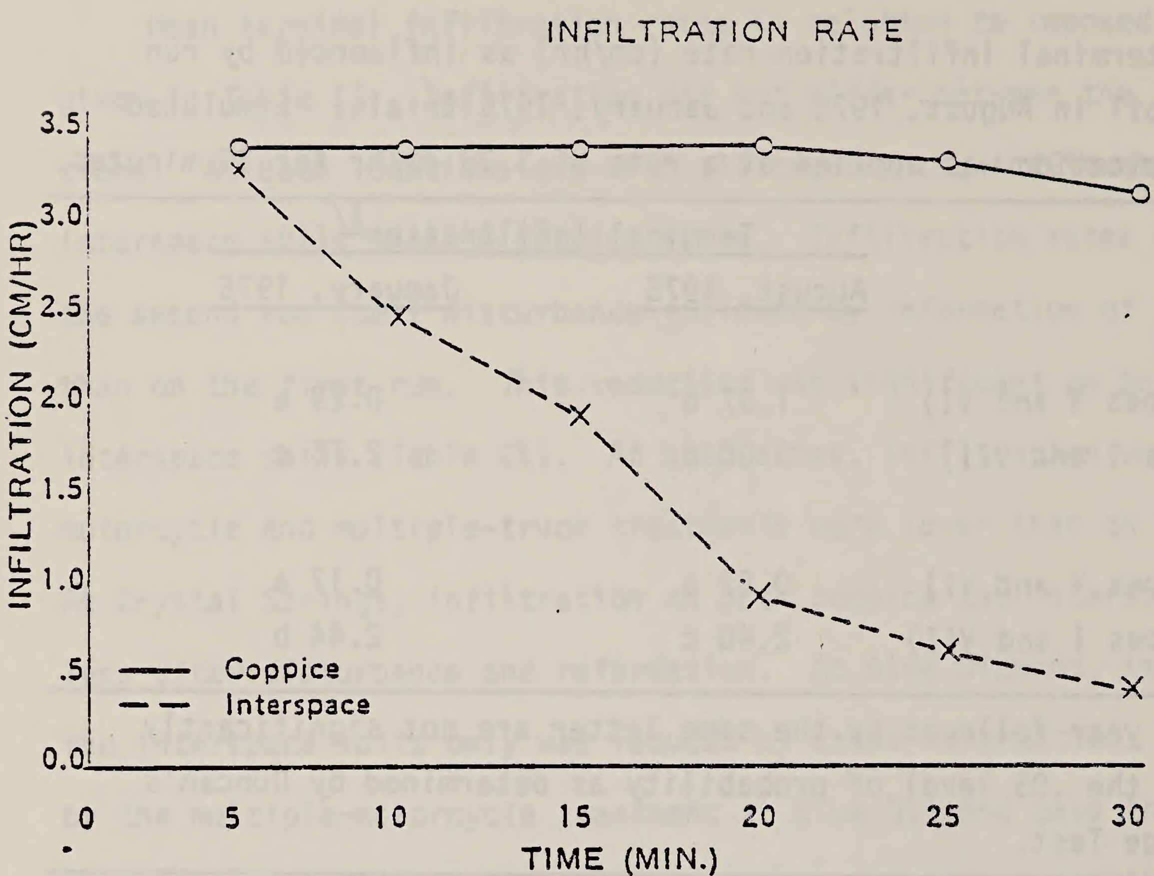
Infiltration rate - August, 1975

Mean terminal infiltration rates in relation to imposed variables are given in Table 23. Infiltration did not differ between the two study locations. At both locations and with all treatments, infiltration was less on interspace soils than on coppice soils. Infiltration rates were lower on the second run (soil disturbance followed by reformation of the surface crust) than on the first run. This reduction was significant on both coppice and interspace soils (Table 25). At both sites, infiltration on the multiple-motorcycle and multiple-truck treatments were lower than on the control. At Crystal Springs, infiltration on both coppice and interspace soils was less after disturbance and reformation. At Blue Diamond, infiltration on the interspace soils only was reduced by crust reformation. Disturbance by the multiple-motorcycle treatment at Blue Diamond gave the greatest reduction in infiltration on the coppice and interspace soils between the first and second runs (Fig. 7). The multiple-truck treatment did not give as large a reduction in infiltration between runs (Fig. 8). Data appear to support results from the January, 1975 trial that indicated an increase in infiltration due to multiple-truck disturbance of interspace soils, particularly after 20 minutes of water application. This response may be caused by powdering the surface crust that restricts water movement. After crust reformation, however, the multiple-truck treatment caused the greatest reduction in infiltration between the first and second runs at both sites and particularly at Crystal Springs on the interspace soils (Table 26). The interspace soils, after severe disturbance, wetting, and drying, form a less permeable crust than before disturbance. In addition, Figure 9 suggests that merely wetting and drying without disturbance, can change the infiltra-

Table 25. Mean terminal infiltration rate (cm/hr) as influenced by run and soil in August, 1975 and January, 1976 trials. Simulated precipitation was applied at a rate of 3.38 cm/hr for 30 minutes.

Run and Soil	Terminal Infiltration[1/] August, 1975	Terminal Infiltration[1/] January, 1976
First		
Interspace (Types V and VI)	1.37 b	0.29 a
Coppice (Types I and VII)	3.00 d	2.76 c
Second		
Interspace (Types V and VI)	0.52 a	0.17 a
Coppice (Types I and VII)	2.40 c	2.44 b

1/ Means within year followed by the same letter are not significantly different at the .05 level of probability as determined by Duncan's Multiple Range Test.



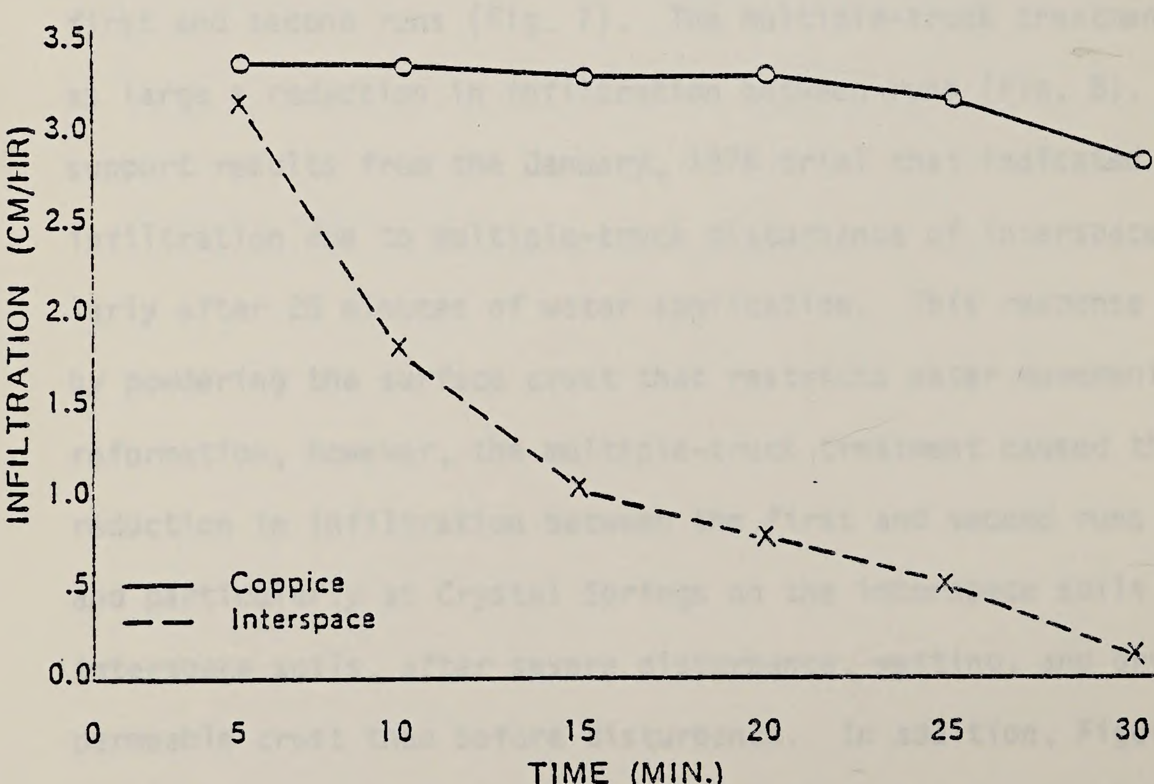
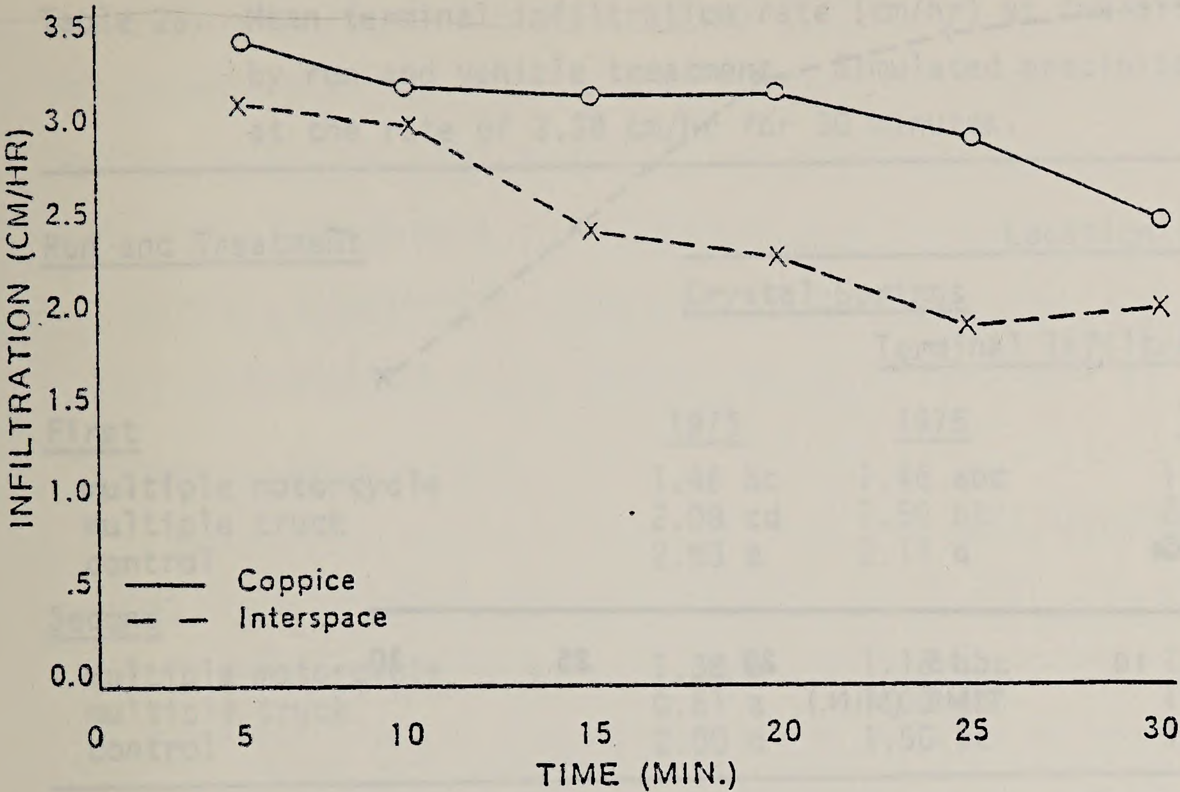


Figure 7. Infiltration curves for the multiple motorcycle treatment at Las Vegas on coppice and interspace soils for the first (upper graph) and second (lower graph) runs.



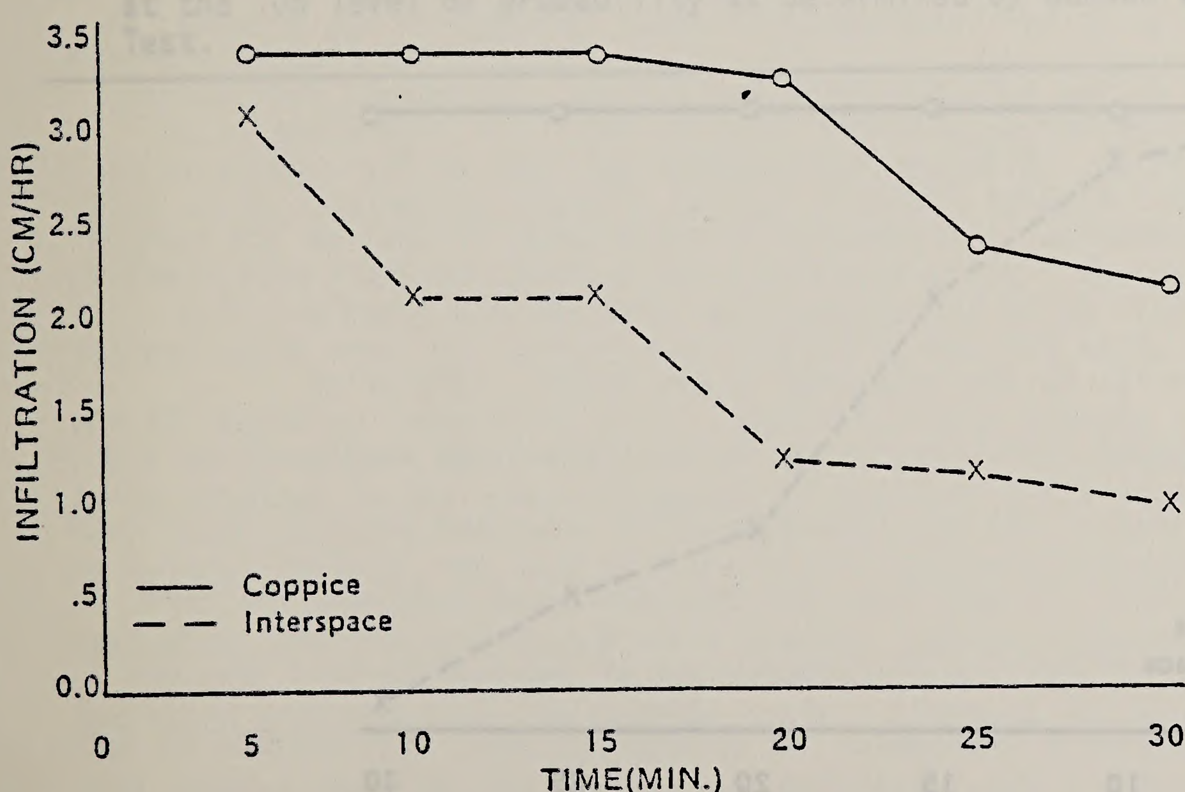
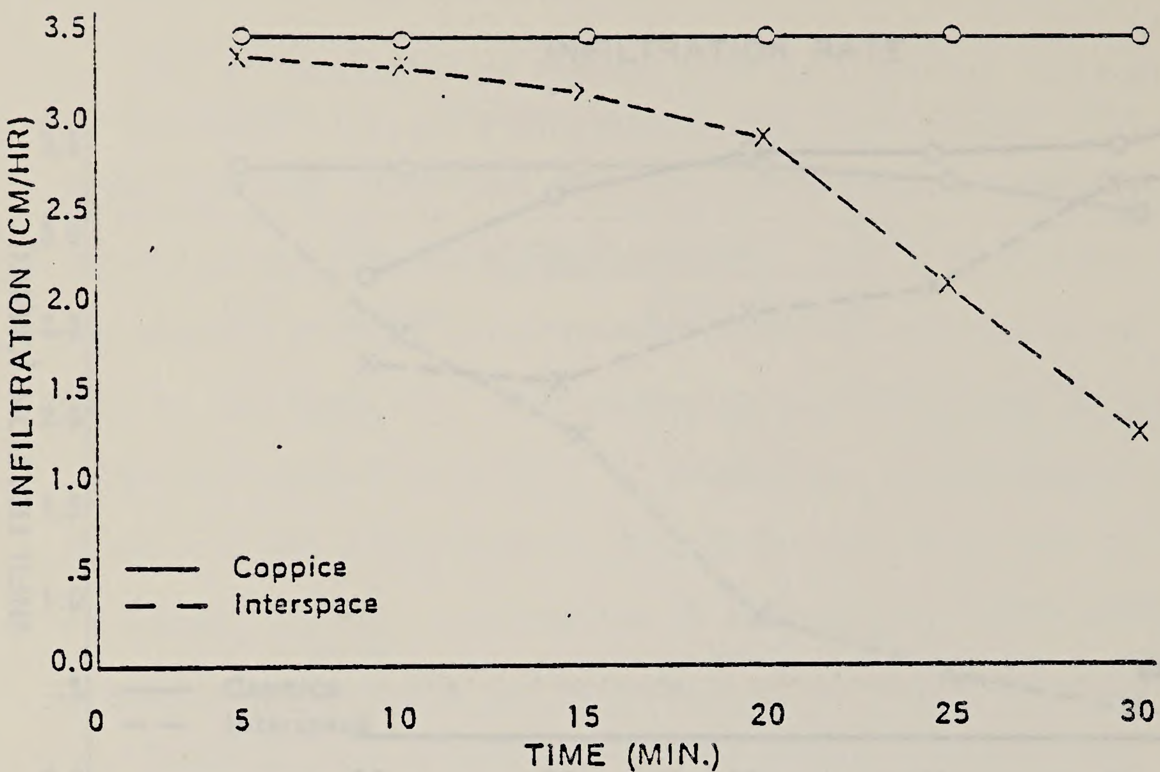


Figure 8. Infiltration curves for the multiple truck treatment at Las Vegas on coppice and interspace soils for the first (upper graph) and second (lower graph) runs.



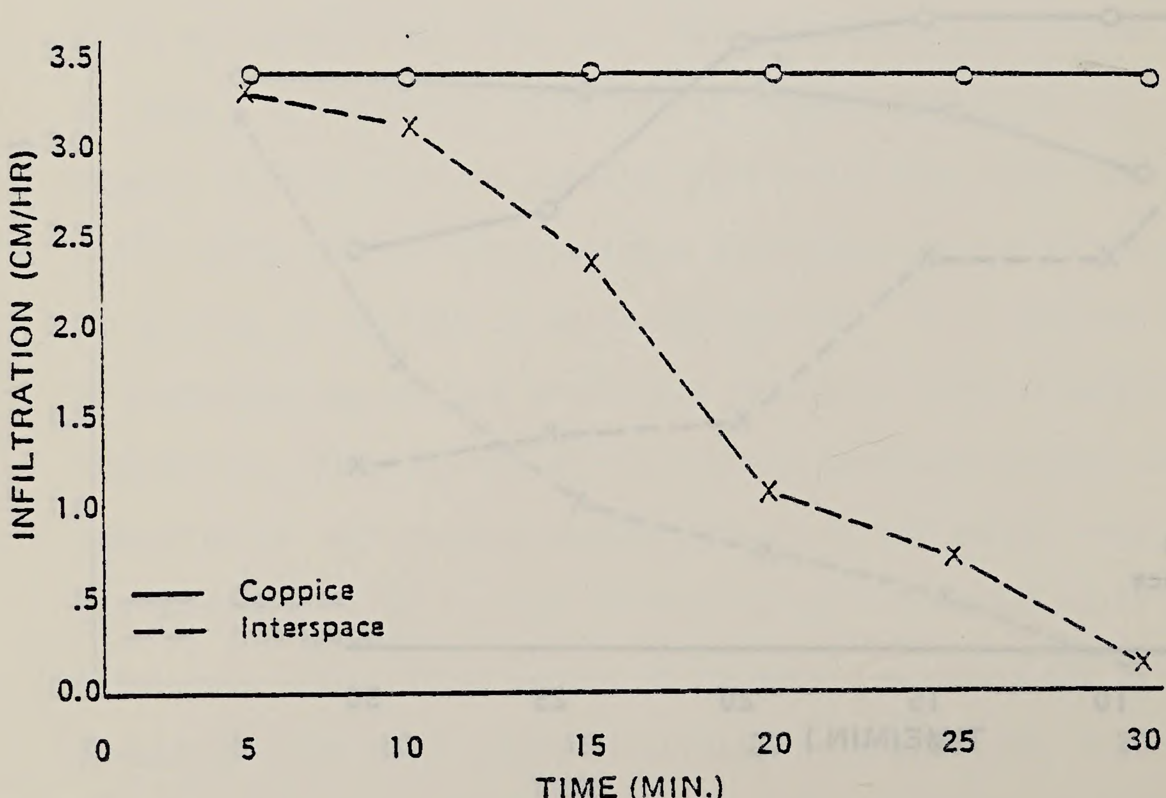


Figure 9. Infiltration curves for the control treatment at Las Vegas on coppice and interspace soils for the first (upper graph) and second (lower graph) runs.

Table 26. Mean terminal infiltration rate (cm/hr) at two sites as influenced by run and vehicle treatment. Simulated precipitation was applied at the rate of 3.38 cm/hr for 30 minutes.

Run and Treatment	Location			
	Crystal Springs		Blue Diamond	
	Terminal Infiltration[1/]			
First	1975	1976	1975	1976
multiple motorcycle	1.46 bc	1.46 abc	1.78 bc	1.36 abc
multiple truck	2.08 cd	1.50 bc	2.18 cd	1.09 ab
control	2.83 e	2.11 d	2.65 de	1.67 cd
Second				
multiple motorcycle	1.38 b	1.18 abc	1.45 bc	1.45 abc
multiple truck	0.61 a	1.03 ab	1.54 bc	0.98 a
control	2.00 c	1.50 bc	1.78 bc	1.68 cd

1/ Means within year followed by the same letter are not significantly different at the .05 level of probability as determined by Duncan's Multiple Range Test.

tion characteristics of interspace soils. The high infiltration capacity of the coppice soils was reduced by the multiple-vehicle traffic on both the first and second runs. Heavy vehicle traffic cuts through the coppice soil and into the underlying horizons that may have lower infiltration rates. The infiltration capacity of both coppice and interspace soils at Crystal Springs was reduced by both multiple-vehicle treatments. At Blue Diamond, infiltration on coppice soils was reduced by multiple-vehicle treatments, whereas infiltration on the interspace soils was reduced by the multiple-motorcycle treatment only.

Infiltration - January, 1976

As in the August, 1975 trial, infiltration rates were similar at both sites, lower after crust reformation, lower on interspace soils than on coppice soils, and lower on both the multiple-motorcycle and multiple-truck treatments than on the control (Table 23).

The reduction in infiltration after crust reformation was greatest at Crystal Springs on the multiple-truck and control treatments, particularly on the coppice soils. Although infiltration was less on the coppice soils after crust reformation, infiltration on these kinds of soil on the control treatment was still 22 to 31% greater than with vehicle traffic. This response was similar to that measured in the August, 1975 trial.

At Blue Diamond, infiltration on the multiple-truck treatment was significantly lower than on the multiple-motorcycle treatment and both were lower than on the control. In addition, the multiple-truck treatment was more damaging to the infiltration characteristics of the coppice soil than was the multiple-motorcycle treatment. At Crystal Springs, infiltration on both traffic treatments were similar and less than on the control. All treat-

ments, including the control, had lower infiltration rates on the interspace soil than on the coppice soils at both locations. In addition, both vehicle treatments decreased the infiltration capacity of the coppice soils. Infiltration on the interspace soils was statistically the same for all treatments at Blue Diamond. However, a trend suggests that the multiple-vehicle treatments increase infiltration rate. At Crystal Springs, infiltration on the control interspace soils was 6 to 14 times greater than on the vehicle treatments but differences were not significant.

Sediment - January, 1975

Sediment production in this trial was higher at Blue Diamond than at Crystal Springs; increased by multiple-vehicle treatments; and was more from interspace soils than from coppice soils (Table 27). The generally greater sediment values here compared to the other trials is due to the greater amount of simulated precipitation applied and the greater chance for detachment and movement of soil particles.

At Blue Diamond, 2.4 times as much sediment was produced from the interspace soils as from the coppice soils. Also all vehicle treatments increased sedimentation from the coppice and interspace soils. The average increase in sedimentation over the control due to traffic was 449 kg/ha on coppice soils and 681 kg/ha on interspace soils. Multiple-truck traffic on interspace soils resulted in the greatest amount of sediment (1674 kg/ha)(Table 28). At Crystal Springs, the multiple-motorcycle treatment caused the most sedimentation from the interspace soils whereas both multiple-vehicle treatments increased sediment from the coppice soils. Although the amount of runoff from coppice soils on the control and multiple-truck treatments was similar, water from the disturbed area carried more suspended sediment.

Table 27. Sediment production (kg/ha) in response to imposed variables. Simulated precipitation was applied at the rate of 7.50 cm/hr for 30 minutes in the first trial and at 3.38 cm/hr for 30 minutes in the following two trials.

Variable	Sediment Production[1/] Jan., 1975	Aug., 1975	Jan., 1976
Study Site			
Crystal Springs	266 a	116 a	109 a
Blue Diamond	787 b	222 b	457 b
Soil			
Interspace (Types V & VI)	703 b	306 b	537 b
Coppice (Types I & VII)	350 a	33 a	30 a
Run			
First	-	147 a	282 a
Second	-	192 a	284 a
Vehicle Treatment			
Multiple Motorcycle	556 b	192 b	273 ab
Multiple Truck	737 b	273 b	451 b
Control	288 a	42 a	126 a

1/ Means within year followed by the same letter are not significantly different at the .05 level of probability as determined by Duncan's Multiple Range Test.

Table 28. Mean sediment production (kg/ha) in response to location, vehicle treatment, and soil. Simulated precipitation was applied at the rate of 7.50 cm/hr for 30 minutes in the initial 1975 trial and at 3.38 cm/hr for 30 minutes in the following two trials.

	Location					
	Crystal Springs			Blue Diamond		
	Sediment Production[1/]					
Vehicle Treatment and Soil	1/75	8/75	1/76	1/75	8/75	1/76
Multiple Motorcycle - Types V & VI	439 c	257 c	265 ab	1001 de	494 d	754 c
Multiple Motorcycle - Types I & VII	315 bc	12 a	15 a	468 b	6 a	57 ab
Multiple Truck - Types V & VI	189 ab	272 c	251 ab	1674 f	649 e	1462 e
Multiple Truck - Types I & VII	324 bc	107 a	14 a	758 c	64 a	76 ab
Control - Types V & VI	258 ab	41 a	101 ab	657 c	122 a	386 b
Control - Types I & VII	70 a	8 a	8 a	164 a	0 a	9 a

1/ Means within year followed by the same letter are not significantly different at the .05 level of probability as determined by Duncan's Multiple Range Test.

Sediment Production - August, 1975

Sediment production (Table 27) was greater at Blue Diamond than at Crystal Springs; less on coppice than on interspace soil; and greater on multiple-vehicle treatments (232 kg/ha) than on the control (42 kg/ha).

Different treatments also gave different results at the two study sites. Both multiple-vehicle treatments on interspace soils resulted in less sediment at Crystal Springs than at Blue Diamond. The interspace soils at Crystal Springs produced 190 kg/ha compared with 42 kg/ha on the coppice soils. At Blue Diamond, the interspace soils produced an average of 421 kg/ha compared with 24 kg/ha on the coppice soils. At both locations, the coppice and interspace soils produced similar amounts of sediment on the control treatment. However, the multiple-vehicle treatments produced significantly more sediment from the interspace soils than from the coppice soils (Table 28). The greatest amount of sedimentation was found on the multiple-motorcycle (494 kg/ha) and multiple-truck (649 kg/ha) treatments on the interspace soils at Blue Diamond.

Sediment Production - January, 1976

The main effects of treatments showed that sediment production was: greater on the Blue Diamond site than at Crystal Springs; similar before and after crust reformation; highest on the multiple-truck treatment; and higher on the interspace soils (Table 27).

Treatment effects were similar at Crystal Springs, however, multiple-truck treatment produced more sediment than the other treatments at Blue Diamond before and after crust formation. Numerically but non-significant differences in sediment were found on the coppice and interspace soils in the control treatment before and after crust reformation. Conversely, both before and after crust reformation, more sediment was produced by the multiple-

vehicle treatments on the interspace soils (688 kg/ha) as on the coppice soils (40 kg/ha) (Table 29). At Crystal Springs, both coppice and interspace soils yielded the same amount of sediment before and after crust reformation, although the trend was for more from the interspace. At Blue Diamond, the trend was significant with an average of 868 kg/ha from the interspace and 44 from the coppice soils.

At Crystal Springs, sediment from the interspace soil due to the multiple-vehicle treatments was 17 times that from the coppice soils. While these differences were not statistically significant, the data do suggest a trend and the trend was significant at Blue Diamond. For example, the multiple-motorcycle treatment resulted in 15 kg/ha sediment from the coppice soils and 754 kg/ha from the interspace soils. The multiple-truck treatment resulted in 76 kg/ha from the coppice soils and 1463 kg/ha from the interspace soils. Even the control interspace soils produced 368 kg/ha compared with 9 kg/ha on the control coppice soils.

Table 29. Sediment production (kg/ha) in response to run, vehicle treatment and soil in 1976. Simulated precipitation was applied at the rate of 3.38 cm/hr for 30 minutes.

Vehicle Treatment and Soil	Run: First	Run: Second
	Sediment (kg/ha)[1/]	
Multiple motorcycle		
Interspace (Types V and VI)	522 bc	497 bc
Coppice (Types I and VII)	24 a	48 a
Multiple truck		
Interspace (Types V and VI)	796 cd	917 d
Coppice (Types I and VII)	38 a	52 a
Control		
Interspace (Types V and VI)	312 ab	175 ab
Coppice (Types I and VII)	3 a	14 a

1/ Means followed by the same letter are not significantly different at the .05 level of probability as determined by Duncan's Multiple Range Test.

Shrub Damage

Multiple-vehicle traffic damaged about 80% of each shrub crown bisected by a wheel track at time of treatment. Estimate of permanent damage in all three trials was made in October, 1976.

At Blue Diamond, apparent death of white bur-sage, joint fir, and box thorn plants resulted from the January, 1976 trial. Damage from the August, 1975 trial ranged from the apparent death of white bur-sage, creosote bush (Larrea tridentata) and joint fir, to 10% regrowth of the crown of spiney hopsage, 20% regrowth of the crown of range ratany, and complete regrowth from the crown of box thorn. Approximately 1 1/2 years after the January, 1975 treatments, spiney hopsage, joint fir, and range ratany in the wheel tracks were dead. White bur-sage crown had 20% regrowth whereas box thorn showed 80% regrowth. These results suggest that white bur-sage, joint fir, range ratany, spiney hopsage, and creosote bush are the species most sensitive to damage by vehicle traffic; whereas box thorn makes vigorous regrowth from the crown even after severe damage.

At Crystal Springs, blackbrush, spiney hopsage, and little-leaf horsebrush (Tetradymia glabrata) all died as the result of January, 1976 treatments. Spiney menodora (Menodora spinescens) had 30% of the crown with regrowth while box thorn had 60% regrowth. The August, 1975 treatments resulted in the death of blackbrush, joint fir, and spiney hopsage. Box thorn and snakeweed (Gutierrezia sarothrae) regrew from the entire crown. After 1 1/2 years, the crowns of blackbrush and spiney hopsage were 90% dead; crowns of joint fir and snakeweed were 60% dead while box thorn had vigorous regrowth and showed no permanent damage as the result of treatment. The results indicate that joint fir and snakeweed are initially damaged but survive, and that box thorn is resistant to vehicle treatments applied.

To summarize, the Blue Diamond site had more interspace soils and less coppice soil than at the Crystal Springs site. Infiltration was the same at the two sites except when heavy precipitation was applied, then infiltration was less at Blue Diamond. Sediment production was always greater at Blue Diamond regardless of the precipitation applied. Infiltration was 2 to 10 times greater on coppice soils and sediment production was 2 to 20 times more in interspace soils. Although infiltration was less after crust reformation, sediment production was similar before and after crust reformation. Both multiple-vehicle treatments reduced infiltration and increased sedimentation over the untreated control soil. Estimates of shrub damage due to vehicle traffic indicated that the dominant and more desirable species are severely injured or killed whereas the undesirable species are only temporarily injured and make rapid and vigorous regrowth.

APPENDIX I

Description of the soils at the four seeding sites, the two off-road-vehicle sites, and the surface soil morphological types at these locations.

APPENDIX I

KINDS OF SOILS AND SOIL SURFACE MORPHOLOGICAL TYPES AT THE SEEDING SITES [1, 2]

The landscape positions, slopes and aspects, soil parent material, kinds of soils, and major soil features for the seeding sites are reported in this appendix. At any one site, the soil profile is uniform across the site except for its microtopography and the related morphology of its uppermost one or two subhorizons. Four major soil surface morphological types were identified as this study progressed, and since they seem to be the major determinants of seedling emergence at a site, brief descriptions follow. When the seedings were established only the general surface morphology distinctions of *coppice* (comprised of type I and type II surfaces) and *coppice interspace* (comprised of type III and type IV surfaces) were made and are used in the preceding thesis.

Type I soil surface morphology. This morphological type occurs on *shrub coppice dune* microtopographic positions. The surficial A11 horizon is an aeolian deposit and is mostly litter, moss, or lichen-covered. It is noncrusted, only very slightly hard, and is weak to moderate very fine subangular blocky structured. It is additionally structured into weak, 5-10 cm diameter, convex topped, squat prisms or polygons which are separated by trench-like, 1 cm wide by 1 cm deep cracks at their tops; these shallow trenches are filled with litter most commonly.

Type II soil surface morphology. This type occurs on *coppice bench* microtopographic positions, which appear to be the flattened, somewhat eroded remnants of former aeolian shrub-coppice dunes. The surficial A11 horizon is only very weakly and very thinly (<2 cm) crusted, and is either massive or massive in its upper part and very weakly platy with depth. The crust is quite fragile. This A11 horizon is additionally structured into barren or lichen-covered, relatively small 7-15 cm diameter squat prisms or polygons which are convex topped, or more commonly support several 1-3 cm high by 2-3 cm diameter *pinnacles*. The

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[1]This appendix was prepared from field soil descriptions by F.F. Peterson, Professor of Soil Science, University of Nevada Reno, and particle size distribution, organic carbon content, and pH analysis by K. Wood.

[2]For complete description of morphological surface types see: R.E. Eckert, M.K. Wood, and F.F. Peterson. 1976. Progress report. Properties, occurrence and management of soils with vesicular surface horizons. Contract 52500-CT5-29(N), Bureau of Land Management and Nevada Agricultural Experiment Station.

polygons are round-shouldered and separated by prominent, trench-like cracks about 1 cm deep and 1 cm wide at their tops. This largely barren, prominently trench-cracked and pinnacled surface stands microtopographically below the coppice dunes and above the type III and IV surfaces. Its trench-cracks seem preferred sites for natural seed lodgement and seedling emergence.

Type III soil surface morphology. This type occurs on gently sloping to flattish *intercoppice microplain* microtopographic positions. The surficial A11v horizon is a massive, moderately coarsely vesicular, durable crust about 1.5-4 cm thick which is separated into squat prisms, or polygons, roughly 13-26 cm diameter. The polygons have angular shoulders and narrow cracks between them. This surface is most commonly barren except for a very few plants rooted in the cracks, but can be lichen-covered where protected from trampling. Some places it has a scattered pebble pavement, other places pebbles lie in rings on top the polygon cracks.

Type IV soil surface morphology. This type occurs in *playette* microtopographic positions which are slight depressions or flats below the intercoppice microplains where water collects and stands briefly after heavy storms. The A11v surficial horizon is a prominent, durable, massive, coarsely vesicular crust from 4-8 cm thick. It is relatively light colored, is quite barren, and is irregularly broken into large, squat prisms or polygons of from 20-36 cm diameter. The polygon shoulders are angular and intervening cracks are narrow.

At the seeding sites, the different A11 horizons of the four types all rest on a continuous, compound very fine platy and very fine subangular blocky A12 horizon. Cow trampling destroys and mixes the upper 2-4 cm of the A11 horizon, but it appears to reform to its original, identifying type morphology within a few years. After a surface has been powdered by trampling, it first slakes to a massive, nonvesicular crust, then reforms its characteristic morphology. The Paradise Valley site showed the most widespread and prominent effects of trampling.

Lower Coil's Creek Site

Soil Identification: Fine, montmorillonitic, mesic, Xerollic Nadurargid.

Landform: A large remnant of a shallowly and sparcely dissected, Pleistocene-aged alluvial fan sloping two percent to the east.

Parent Material: Fanglomerate from volcanic rocks of the Simpson Park Range, probably with a thin loessial mantle on top the relict Pleistocene soil.

Elevation and Orographic Location: This site is at about 2,100 m elevation and is about 10 km southeast of the roughly 2,400 m Simpson Park Range crest.

Soil Surface Morphological Types: The ochric epipedon is a relatively thick (30-35 cm) loam which feels notably silty in its upper part and sticky in its lower part. It consists of about 55 percent silt plus very fine sand and behaves more nearly as a silt loam than as a loam, i.e., it shows some dilatency. Its thickness might reflect loess addition and the clay increase in the lower A horizon might reflect post-Pleistocene illuviation, whereas the clay-textured natric horizon is a Pleistocene relict.

The epipedon consists of three distinct subhorizons: (1) The lowermost part is a laterally continuous, blocky, relatively hard and sticky A2 horizon. (2) The middle A12 horizon is a weak very fine platy and moderate very fine subangular blocky, laterally continuous layer. (3) The surficial A11 horizon is laterally discontinuously crusted and presents four distinctive morphologies and surficial physiognomies.

At this site, roughly 1 percent of the area has a thickly crusted (4-7 cm), massive, coarsely vesicular, barren A11v, or type IV surficial horizon playette microtopographic positions. Roughly 41 percent of the site has a moderately thickly crusted (about 3-4 cm), coarsely vesicular, massive, very sparcely vegetated, A11v, or type III surface in intercoppice microplain positions; the following illustrative pedon is from a type III area. Roughly 30 percent of the site has a thinly crusted (<2 cm), or noncrusted, massive, pinnacled, A11 or type II surface which is only slightly hard and occurs in coppice bench microtopographic positions. This type II surficial horizon has small shrinkage polygons (7-15 cm diameter) separated by 1-cm wide, trenchlike cracks. Comparatively, the type I and II surfaces have larger polygons with narrow intervening cracks. Roughly 28 percent of the site consists of

shrub coppice dunes with friable, moderate very fine subangular blocky A11 horizons, or type I surface. The A11 horizon formed by the coppice was found by morphological tracing to be an aeolian deposit on top of a type III subhorizon. Sand separate percentages verify this morphological observation. Where a type III A11v horizon is buried by a type I A11 horizon, the type III material has lost its vesicularity and becomes a platy part of the A12 horizon. The type I A11 horizon has about 15 percent (absolute) more sand, and less silt and clay than the type III A11v horizon. It also has about 3.6 percent organic carbon compared with 1.6 percent in the type III surface.

Soil Profile Features: The soil at this site has a platy, indurated, continuous duripan with a very abrupt, irregular to wavy upper boundary at about 70 to 90 cm depth. The natric horizon is a very sticky, very plastic clay which is compound moderate, medium columnar and weak, fine angular blocky in its upper part and moderate to weak fine blocky in its lower part. There is an *abrupt textural boundary* at the top of the natric horizon, and the overlying 5 to 10 cm of A2 horizon has a relatively light, or bleached-appearing color which might reflect periodic, brief saturation in the lower A horizon, on top the clayey B21t horizon. A few roots do penetrate through the natric horizon and form a mat on top the duripan. The natric horizon identification is tentatively based on 1:5 dilution pH values of from 8.4-8.9, which suggest an exchangeable sodium percentage of 15 or greater. The columns of the upper 10 cm of the natric horizon are dusted with bleached, whitish, very fine sand, suggesting some significant leaching. Pedogenic calcium carbonate has accumulated in only the lowermost natric horizon and duripan, also suggesting significant leaching. Should the B2t horizon prove to have less than 15 percent exchangeable sodium due to leaching, the soil would be identified as an Abruptic Xerollic Durargid.

Illustrative pedon of the fine, montmorillonitic, mesic, Xerollic Nadurargid at the Lower Coil's Creek Site[1]

Horizon	Depth cm	Color		Texture	Structure	Consistence			1:5 pH	$CaCO_3$	Roots	Boundary	Coarse Fragments % vol.
		Dry	Moist			Dry	Moist	Wet					
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)
A11v[2]	0-4	2.5Y 6/2	2.5Y 4/2	l	m	vsh	fr	so/ps	7.7	eo	0	as	<5
A12	4-16	10YR 6/3	10YR 4/3	l	1vfpl & 2vfsbk	sh	fr	ss/p	7.8	eo	1	as	<5
A2	16-32	10YR 6/4	10YR 4/3	l+	1cpr & 1fsbk	sh	fr	s/p	8.2	eo	1	vaw	<5
B21t	32-54	7.5YR 6/4	7.5YR 4/6	c	2mcpr & 3fabk	h	fi	vs/vp	8.4	eo	1	cw	<5
B22t	54-71	10YR 6/5	10YR 5/4	c	2fabk	h	fi	vs/vp	8.6	e	1	cw	10
B23tca	71-81	10YR 6/5	10YR 5/4	cl	1fabk	h	fi	vs/vp	8.9	e	1	vai	30
Clsicam	81-91+	10YR 8/4	10YR 6/4	...	m	cs	...	...	9.1	ev	[3]	...	50

[1]See key to morphological abbreviations at end of this appendix. Type III soil surface.
[2]Has many about 0.5-1mm vesicular pores.
[3]Root mat on top of duripan.

Upper Coil's Creek Site

Soil Identification: A complex of *fine, montmorillonitic, mesic, Xerollic Duragids*[1] and *fine, montmorillonitic, mesic, Xerollic Nadurargids.*

Landform: The soil occurs on a remnant of a moderately deeply dissected Pleistocene-aged alluvial fan sloping two percent to the east. The site is on the transversely-flattish top of a fan remnant which has well rounded shoulders and stable side slopes.

Parent Material: Fanglomerate from volcanic rocks of the Simpson Park Range, probably with a thin loessial mantle on top the relict Pleistocene soil.

Elevation and Orographic Location: The site is at about 2,200 m elevation, and is about 8 km downslope and east of the roughly 2,400 m crest of the Simpson Park Range. We have seen this site receive moderate rainfall when the Lower Coil's Creek was receiving at most light showers.

Soil Surface Morphological Types: The ochric epipedon is a marginal silt loam in its upper part becoming a heavy silt loam on light-silty clay loam in its lower part. It contains 40-45 percent silt and 11-15 percent very fine sand. It has about the same proportions of surface morphological types as the Lower Coil's Creek Site (Table 1), but the type IV playettes are noticeably scarcer, though present, and the extensive type III intercoppice microplains are noticeably *less durably crusted.* Here the type III A11 horizon is most commonly compound weak very fine platy and weak very fine subangular blocky rather than massive. Furthermore, it mostly has either fine vesicular pores (<0.5 mm) or tubular pores rather than the coarse vesicular pores associated with more durably crusted type III surfaces at other sites. Perhaps because of lack of vesicularity, the type III surface is firmer underfoot than at the other sites and shows relatively little trampling disturbance. At this site, *Phlox* plants rooted in the polygon cracks of the type III surface are notably common, whereas this type surface is largely barren at the other sites.

The type I, II, and IV surfaces are like, or very similar to those at the Lower Coil's Creek site, except for the scarcity of the type IV surface.

Limited data (Table 2) suggest the occurrence of a weakly crusted (i.e., weakly structured rather than massive) type III surface here is related to somewhat greater humus contents than at the other sites. Probably the relatively lesser degree of slaking and crusting observed in the plowed seeding plots at this site are also a reflection of higher humus contents and some degree of structure in the A11 and A12 horizons.

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[1]This is an unofficial, *ad hoc* soil family identification and is not listed in the 1975 U.S. Soil Taxonomy.

Soil Profile Features: The Durargids and Nadurargids, which occur in a complex of unknown proportions of small polypedons at this site, are similar except for exchangeable sodium accumulation in the B2t horizon (i.e., alkaline pH) and an abrupt textural boundary between the A and B2t horizons in the Nadurargids. The possibly more extensive Durargids are neutral throughout their sola and lack an abrupt textured A to B2t boundary. Both soils have a continuous, strongly cemented duripan at from 60-75 cm depth; it is calcareous throughout in the Nadurargid but noncalcareous in its upper part in the Durargid. Both soils have clayey B2t horizons of about 35-50 cm thickness but that of the Nadurargid is compound columnar and blocky in its upper part whereas that of the Durargid is only blocky in its upper part.

Both soils have about 18-24 cm thick A horizons which are marginal silt loams (i.e. just 50± percent silt) that become somewhat more clayey with depth. They contain nearly 50 percent silt and about two-thirds of their sand is fine and very fine sand so they behave as silt loams.

An A2 horizon occurs over the natric horizon of the Nadurargid but is absent from the Durargid. Both soils have continuous, characteristically compound very fine platy and very fine subangular blocky A12 horizons. All horizons of type I, II, and III morphology occur on both soils, but the type IV surface was found only on Nadurargids.

The humus contents of these soils are high enough that they would be Mollisols if the A horizons were not too light colored. Humus contents at this site are as great or greater than those in the soils at the other sites (Table 2).

Illustrative pedon of the fine, montmorillonitic, mesic, Xerollic Durargid at the Upper Coil's Creek Site.[1]

Horizon (1)	Depth cm (2)	Color: Dry (3)	Color: Moist (4)	Texture (5)	Structure (6)	Consistence: Dry (7)	Consistence: Moist (8)	Consistence: Wet (9)	1:5 pH (10)	$CaCO_3$ (11)	Roots (12)	Boundary (13)	Coarse Fragments % vol. (14)
A11[2]	0-5	2.5Y 6/2	10YR 3/3	l	1vfpl & 1vvfsbk	sh	fr	so/ps	7.8	eo	1	as	<5
A12	5-18	2.5Y 6/2	10YR 3/3	l	2vfpl & 2vvfsbk	sh	fr	ss/ps	7.8	eo	1	aw	<5
B1t	18-27	10YR 5/3	10YR 4/3	cl	3vfsbk	h	fr	s/p	7.9	eo	1	aw	5
B21t	27-37	10YR 5/3	10YR 4/3	cl+	1fpr & 3fsbk	h	fr	vs/p+	8.0	eo	1	aw	3
B22tsi	37-50	10YR 5/3	10YR 4/3	c	3f-mpr & 2fabk	vh	fi	vs/vp	7.8	eo	1	aw	3
B23tsi	50-61	10YR 6/3	10YR 4/3	c	3fabk	h	fr	vs/vp	8.0	eo	1	aw	10
C1sim	61-72	10YR 6/3	10YR 4/3	cl	1mpl	cw	fi	s/p	8.0	eo	1	vaw	...
C2sicam	72+	10YR 8/2 & 10YR 6/3	10YR 6/3 & 10YR 4/3	...	m	cw	...	...	...	e	0	...	...

[1]See key to morphological abbreviations at the end of this appendix. Type III surface.
[2]Only a few <0.5 mm vesicular pores.

Panther Canyon Site

Soil Identification: A *fine-loamy, mixed, mesic, Xerollic Natrargid.*

Landform: A loess-mantled remnant of a Pleistocene mountain valley-fill plain sloping four percent to the west. This roughly 400 yard wide remnant valley-fill surface is bounded by a 200 foot ridge to the north, a 400 foot ridge to the south, and is roughly half a mile east of the western margin of the Sonoma Range at its southern end.

Parent Material: The relict Pleistocene II B2tcab horizon of this soil has formed from mixed volcanic alluvium from the Sonoma Range. The roughly 20-inch thick loess mantle is probably late-Pleistocene to Recent aged and was blown in from the Carson Desert and Buena Vista Valley to the west. Dust high in soluble sodium salts is presently blowing out of those areas and apparently being deposited at this site, accounting for the strongly alkaline soil reaction.

Elevation and Orographic Position: This site is at 1,650 m elevation, It is roughly 0.8 km within a major valley-and-pass sag on the west slopes of the Sonoma-Tobin Range, eastern margin of Grass Valley. Vegetation suggests a significantly greater precipitation (big sage-brush, grasses) than on the floor of Grass Valley (shadscale).

Soil Surface Morphological Types: This site is peculiar in that it has 72 percent type II coppice bench surfaces, 27 percent type I coppice surfaces, a possible trace of type III surface, and no type IV playette surfaces. Apparently the type II surface morphology is formed on both coppice bench and intercoppice microplain positions because the 57-62 cm thick, loam textured epipedon is pervious enough, and has great enough waterholding capacity that it doesn't saturate at the surface even in microplain positions. (Saturation is an apparent requisite for vesicular crust formation). Around the margins of the seeding site, where the loess mantle is thinner over the relict B2t horizon, both type III and IV surfaces occur. The loamy epipedon is marginal to a silt loam, having a total of about 70-75 percent silt, very fine sand, and fine sand. It behaves as a silt loam. The humus content is great enough, and deeply enough incorporated that the epipedon would be mollic were it not too light colored.

Because of the extensive type II surface, trench-cracks are a prominent feature where the soil hasn't been recently trampled. Field observation suggest the trench-cracked type II surface reforms in a couple years after trampling at this site.

Soil Profile Features: The thick loessial mantle is the most noteworthy soil feature. It comprises an ochric epipedon, a minimal natric horizon, and a thin C1ca or C1 horizon sequence overlying a buried Pleistocene relict IIB2tcab horizon. The latter horizon is clayey, prominently prismatic and blocky, and modestly charged with pedogenic $CaCO_3$ related to the overlying solum.

This soil keys out to be a Natrargid, presuming the alkaline B2t reactions indicate sufficient exchangeable Na, regardless of whether the upper or buried B2t horizons are considered the diagnostic natric horizon. However, the taxonomic identification is undoubtedly *misleading* for estimation of rooting environment or water movement. There is no shallow, abrupt A/B2t textural boundary as in most Natrargids, and the minimal upper natric horizon doesn't show any morphological properties associated with restricted rooting.

Illustrative pedon of the fine-loamy, mixed, mesic Xerollic Natrargid at the Panther Canyon Site.[1]

Horizon	Depth cm	Color		Texture	Structure	Consistence			1:5 pH	$CaCO_3$	Roots	Boundary	Coarse Fragments % vol.
		Dry	Moist			Dry	Moist	Wet					
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)
A11[2]	0-4	2.5Y 6/2	10YR 4/2	l-	1vfpl & 2vfsbk	sh	fr	ss/sp	8.3	eo	1	as	<1
A12	4-17	10YR 6/2	10YR 4/3	l	2vfpl & 2vvfsbk	sh	fr	s/p	8.8	eo	3	as	<1
B2t	17-34	10YR 6/3	10YR 5/3	l+	1fpr & 2f-msbk	h	fr	s+/p	9.1	eo	2	ai	<3
C1ca[3]	34-62	10YR 7/3	10YR 5/3	sil	1msbk	h	fr	s/p	9.9	ve-es	1	as	<5
II B21tcab	62-104	10YR 6/3	10YR 5/3	c-	1fpr & 3fsbk	vh	fi	vs/vp	9.7	e-ev	1	cs	<8
II B22tcab	104-120+	10YR 6/3	10YR 5/4	c-	1vfsbk	h	fr	vs/vp	9.4	e-es	1	...	35

[1]See key to morphological abbreviations at the end of this appendix. Type II surface.
[2]All horizon has a weak, 0.5-1 cm thick, massive, finely (<0.5 mm) vesicular surficial crust on top structured major part.
[3]Along most of pit wall the IC1 horizon is noncalcareous, whereas the II B2t horizon is continuously calcareous.

Paradise Valley Site

Soil Identification: A *fine, montmorillonitic, mesic, Xerollic Nadurargid.*

Landform: The soil occurs on a moderately extensive, loess-mantled alluvial fan toeslope sloping three percent to the east.

Parent Material: The relict B2t horizon and duripan have formed in fanglomerate from mixed volcanic rocks, shale, mudstone, siltstone, sandstone, carbonate rock, and perhaps granodiorite of the Santa Rosa Range. The epipedon is probably a mantle of Pleistocene Humboldt loess, but since it is not thick enough at this site to contain a *ca* horizon, the underlying B2t horizon is not formally designated as a buried horizon.

Elevation and Orographic Position: This site is at 1,350 m elevation about 8 km east of the abrupt southern terminus of the 1,800 to 2,400 m ridgeline of the Santa Rosa Range. Since is is essentially out onto the Paradise Valley floor, and at the lowest elevation of the seeding sites, it probably has the least precipitation of the sites.

Soil Surface Morphological Types: This site has the greatest proportion of type III intercoppice microplain surface and lowest proportion of type I coppice surface of all the seeding sites (Table 1). The epipedon is a silt loam marginal to a loam, but since it contains roughly 50 percent silt, 20 percent very fine sand, and 10 percent fine sand, it behaves as a silt loam and exhibits marked dilatency slaking. Slumping and crusting of plowed areas is most prominent at this site. The humus content of the intercoppice microplain pedon is just great enough to justify, or force identification as a Xerollic subgroup, but the light color and behavior of the epipedon might better be considered that of a typic subgroup of Nadurargids. The epipedon, and presumably the loess mantle, is about 25-28 cm thick.

The majority of the site has been heavily trampled and traffic paths between coppices are prominent because of their barren slaked, smooth, light colored, massively crusted (about 2 cm thick) surfaces. Reformation of surficial morphology after trampling doesn't seem to have occurred as rapidly at this site as at the Panther Canyon site, and trampling has been more disruptive than at the Upper or Lower Coil's Creek sites. Within a 38 year old exclosure adjacent to this site, surficial morphology has reformed and both type II and III surfaces have extensive lichen cover; even small parts of type IV surfaces have some lichen cover within the exclosure. Lichen cover is relatively sparce outside the exclosure.

Soil Profile Features: The Nadurargids at this site have a clayey, about 60 to 75 cm thick natric horizon very abruptly overlying a continuous, coarsely platy, weakly to moderately cemented, calcareous duripan similar to that at the Coil's Creek sites. The upper part of

the natric horizon is least clayey, and probably represents latest-Pleistocene or Recent illuviation, perhaps in an early loess mantle. Since ground water is deep at this site, sodium accumulation is probably the result of salt dust fall, in Recent time, and lack of leaching as can be postulated for the other sites.

The A2 horizon present at this site is like that in the Nadurargids at the Coil's Creek site, and one outside the site at Panther Canyon where the loess mantle is thin. Its occurrence emphasizes the close similarity of the soils at the Coil's Creek sites and this site, except for the relatively low humus content and somewhat greater silt-very fine sand content of the epipedon at this site. The Coil's Creek sites and this Paradise Valley site all have extensive, vesicular-crusted type III intercoppice microplain soil surfaces and some type IV playette surfaces. In comparison, the lack of type III and IV surfaces at the Panther Canyon site suggests its thicker loessial mantle is the factor which favors formation of its extensive type II surface.

Illustrative pedon of the fine, montmorillonitic, mesic, Xerollic Nadurargid at the Paradise Valley Site.[1]

Horizon (1)	Depth cm (2)	Color Dry (3)	Color Moist (4)	Texture (5)	Structure (6)	Consistence Dry (7)	Consistence Moist (8)	Consistence Wet (9)	1:5 pH (10)	$CaCO_3$ (11)	Roots (12)	Boundary (13)	Coarse Fragments % vol (14)
A11v[2]	0-6	2.5Y 6/2	2.5Y 4/2	sil-	m	sh	fr	so/ps[3]	8.6	eo	1	aw	<3
A12	6-17	2.5Y 7/2	2.5Y 5/2	sil	3fpl	sh	fr	so/ps[3]	8.6	eo	1	as	<2
A2	17-25	2.5Y 7/2	2.5Y 5/2	sil	1csbk	sh	fr	so/ps[3]	8.7	eo	1	as	<2
B21t	25-49	10YR 6/3	10YR 4/3	cl+	1mpr & 3msbk	h	fi	vs/p	9.0	eo	2	cw	8
B22tca	49-78	10YR 6/3	10YR 5/4	c	3mpr & 3msbk	h	fi	vs/vp	9.3	e	1	as	10
B3ca	78-88	10YR 7/3	10YR 5/4	cl+	2m-fsbk	sh	fr	vs/p	9.1	es	0	as	15
C1sicam	88-102+	2.5Y 8/2 & 2.5Y 6/3	...	...	1cpl	cw	...	...	8.9	ev	0	...	20

[1]See key to morphological abbreviations at the end of this appendix. A trampled type III surface.
[2]The upper 2-3 cm of the A11v horizon is massive and nonvesicular due to trampling. The remainder 0.5-1 mm vesicular pores.
[3]Exhibits pronounced dilatency when saturated.

Table 2 Weighted average organic carbon contents for 0-18 cm and 0-40 cm depth zones for surface types at seeding sites.

Surface Type:	Type I		Type II		Type III		Type IV	
Depth Zone:	0-18 cm	0-40 cm	0-18 cm	0-40 cm	0-18 cm	0-40 cm	0-18 cm	0-40 cm
	%	%	%	%	%	%	%	%
Lower Coil's Creek:	2.2[1]	1.5[1]	...	...	1.1	0.9	...	...
	2.3	1.5	...	...	...	...	...	...
Upper Coil's Creek:	2.3	...	...	...	1.5	1.1	...	...
	2.4	1.4[2]	...	...	1.3	0.9	...	...
	...	...	...	...	1.0[2]	...	...	...
Panther Canyon:	2.7	1.6	1.1	0.8	...	...	...	...
Paradise Valley:	1.4	0.9	1.1	...	0.7	0.6	0.4	...
	1.2[2]	...	...	...	0.8	...	...	...

[1]A set of two values on-line for any surface type represent data for a single pedon for its 0-18 and 0-40 cm depth zones.
[2]Sample for lower few cm of depth zone not taken, organic carbon percentage estimated from similar pedon at site to calculate weighted average value.

KINDS OF SOILS AND SOIL SURFACE MORPHOLOGICAL TYPES AT OFF-ROAD VEHICLE STUDY SITES

Crystal Springs Site

Soil Identification: *Loamy-skeletal, mixed, thermic, shallow, Typic Durorthid*

Location: About 9 km west of the White River floodplain at Crystal Springs, along Nev. Hwy. 25, and 0.8 km north of the highway.

Landform Position: On tops of long, narrow, transversely level-topped alluvial fan remnants which have well-rounded shoulders (ballena-like form) and narrow interfluves filled with relatively younger alluvium. Fan remnants slope 5 percent to the east.

Parent Material: Fanglomerate from ash-flow tuffs (ignimbrite), limestone, dolomite, shale, and sandstone of the Pahranagat Range, with a probable, thin loess addition infiltrated into the loamy-skeletal fanglomerate parent material.

Elevation and Orographic Location: The site is at about 1,200 m elevation and is roughly 9 km east of the 1,850 to 2,100 m ridgeline of the Pahranagat Range.

Vegetation: *Coleogyne ramosissima* (blackbrush), *Lycium andersoni* (box thorn), *Ephedra nevadensis* (joint fir), *Menodora spinescens* (spiney menodora), little or no grass and a few, sparse annuals.

Soil Surface Morphological Types: Different soil surface morphological types occur here in southern Nevada, as compared with the north-central Humboldt loess belt. Here the soil surface physiognomy is dominated by a closely spaced *pebble pavement*, rather than by the polygonally cracked, largely mazic fine earth surface of the loess belt soils. Both areas have vesicular crusted surficial horizons, but in the loess belt it is exposed, whereas here it is masked by the pebble pavement.

The pebble-mantled Aridisols of this southern Nevada area seem -- very tentatively -- to have three main surface morphological types:

Type V. *Embedded pavement type:* Pebble-pavement *embedded* in a vesicular crusted surficial horizon. Possible horizon sequence notation:

Pem: Embedded pebble pavement; pebbles buried about half way in vesicular fine earth; are held firmly against dislodgement.

A11v: Massive (very coarsely prismatic, or polygonal), vesicular, relatively pebble-free, relatively greyish colored "crust".

A12 : Weakly platy, or blocky, relatively greyish, more finely vesicular, or nonvesicular lower part of A horizon. Might prove to have consistently highest percent clay for A horizon, perhaps for many profiles.

B2 : Relatively reddish-brown colored, relatively gravelly.

This embedded-pavement, vesicular crusted surface occurs on all apparent playette positions, and on what look to be gently sloping or flat intercoppice microplain positions. The most prominent embedded pavement areas are not necessarily in microdepressions (playettes), rather seem to be on micro-flats which grade into gently sloping intercoppice microplains. It might be useful to try the term *paraplayette* for these near-flats; they retain heavy rainfall against lateral runoff long enough during observed storms to look slightly flooded, perhaps because of their pebbled surface as well as their gentle slope.

This tentative type V *embedded*-pavement surface is *barren*, strikingly so. Its polygonal crust structure is not visible to the eye, and there no sparse vegetation was seen rooted in cracks. It covers, very roughly, 16% of the site.

Type VI. *Pebble-mulch pavement type:* Loose pebble pavement setting on top a thin (0.5-6 cm) but identifiable, loose, or soft, very gravelly loamy sand *mulch* layer, which in turn overlies a vesicular, crusted, relatively pebble-free, relatively grey, loamy layer. Possible horizon sequence notation:

Plo : Loose pebble mulch pavement; pebbles not noticeably embedded in fine earth of underlying layer.

A11 : Loose or soft very gravelly loamy sand mulch layer.

A12v: Massive (very coarsely polygonal), vesicular, relatively pebble-free, relatively greyish colored loamy "crust".

B2 : Relatively reddish-brown colored, relatively gravelly, loamy horizon.

The loose, pebble-mulch pavement, or type VI surface occurs on intercoppice microplains, and on slightly more microtopographically raised areas which might be considered coppice benches. The A11 gravel-mulch layer ranges from 1 to 6 cm thick, is thinnest at an embedded pavement margin, and thickest at a coppice margin. This surface type covers very roughly 49.3% of the site.

Type VII. *Animal-spoil areas:* These occur in coppices and on coppice bench-like areas. Annual vegetation grows on these disturbed areas. Characterized by a sparse, partially embedded pavement (true erosional pavement) scattered across brownish fine earth resulting from animal mixing of A and B horizons. Either no, or a thin (<3 cm), finely vesicular, slightly hard crust occurs at the surface.

Many of the small shrub coppices of the Crystal Springs site are composed of animal spoils. However, most are typical gravel and aeolian sand accumulations which form mulches over greyish, platy, nonvesicular, lateral extensions of the A11v, or A12v vesicular horizon of adjacent microplains.

Soil Profile Features: In comparison with the Humboldt loess belt sites, the most distinctive soil differences at this ~~site~~ are: (1) The dominant pebble-mulch surface of the microplains compared with fine-earth surfaces to the north. (2) The inextensive, but prominent embedded pavement surfaces of the paraplayettes, compared with the pebble-free, grey, fine earth playette surfaces to the north. (3) The small coppices, and their pebbled surface, or animal worked surface, compared with the notably conical, litter covered coppices to the north. (4) The lack of prominent coppice benches here, and the occurrence of prominently animal worked, perhaps "pseudo" coppice benches instead. (5) The shallowness of the duripan (i.e., at about 18 cm rather than 60-90 cm). (6) The lack of an argillic horizon and an abrupt A/Bt textural boundary.

Here both the loose gravel mulch surface (type VI) and embedded pavement surface (type V) occur both on the transversely level ballena tops and on the gentle sideslopes. ~~To~~ the north, type III surfaces occur on sideslopes, but the type V playettes are replaced by solufluction affected "solettes".

In the Typic Durorthid at this site, the A12v and B2 horizon do not physically separate in the hands, as do the A and Bt further north; rather they cohere and can be removed as a single thick, polygonal, or very coarsely prismatic "crust". The A and B2 horizons here are distinguished by the A11 and A12v horizons being greyer, the B2 more reddish-brown, and the A12v horizon being somewhat more clayey than the B2 horizon. The entire solum is violently effervescent and very strongly alkaline. The duripan is composed of strongly cemented nodules and irregularly shaped coarse plates; it overlies sandy skeletal or skeletal fanglomerate.

Illustrative pedon of the loamy-skeletal, mixed, shallow, thermic, Typic Durorthid at the Crystal Springs site[1]

Horizon	Depth cm	Color		Texture	Structure	Consistence			1:5 pH	$CaCO_3$	Roots	Boundary	Coarse Fragments % vol.
		Dry	Moist			Dry	Moist	Wet					
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)
Plo	0-1	...	...	2-3 cm dia. pebbles	sg	lo	lo	NA	NA	NA	none	vas	>95
A11	1-3	2.5Y 6/3	2.5Y 4/2	gls	m	vsh	vfr	so/po	8.6	ev	none	vas	36
A12v[2]	3-5	2.5Y 7/2	2.5Y 4/2	sl	2vcopl & 3vcopl	sh	fr	ss/po	8.6	ev	none	vas	15
B2si	5-18	10YR 7/3	10YR 4/3	gl	1fsbk[3]	h	fi	s/p[4]	8.6	ev	few	ci	36
Clsicam	18-35	10YR 7/2, 7/3, 8/1	10YR 6/3, 7/1	NA	1vfsbk & nodules & 3vcopl	--------cs-------			8.8	ev	few	...	>55

[1] See key to morphological abbreviations at the end of this appendix. Type VI soil surface; microplain position.
[2] Has fine 1.0-1.5 mm dia. vesicles.
[3] Has coarse columns in upper 3 cm of B2 horizon.
[4] Increase in stickiness and plasticity compared with Allv appears to be due to increased silt and very fine sand content rather than clay.

Blue Diamond Site

Soil Identification: Loamy-skeletal, carbonatic (?), thermic, shallow, Typic Paleorthid.

Location: S.16 T.22N R.59E, about 7 km due SW from center of Las Vegas, north side of Blue Diamond road.

Landform: On transversely level remnant of old dissected alluvial fan remnant which has a shallow surficial drainage pattern emptying into dissecting fluves. Fan remants slope 2 percent to the northeast.

Parent Material: Fanglomerate from limestone, siltstone, conglomerate, sandstone from the Spring Mountains, with a possible thin loess addition infiltrated into the skeletal fanglomerate.

Elevation and Orographic Location: This site is at about 1,000 m elevation and is about 11 km east of the roughly 2,100 m ridgeline of the southern Spring Mountains.

Vegetation: Larrea tridentata (creosote bush), *Grayia spinosa* (spiney hopsage), *Ambrosia dumosa* (white bur-sage), *Yucca baccata* (yucca), *Ephedra nevadensis* (joint fir), annuals on animal-spoil areas (i.e., coppices and pseudo-coppice benches); microplains essentially barren.

Soil Surface Morphological Types: The soil surface types are quite similar to those pebble paved ones of the Crystal Springs site. The type VI pebble mulch surface on the microplain position covers roughtly 18% of the site. Type VII animal-spoil surfaces and coppices cover 14.2% of the site. Type V embedded pavement surfaces on microplain flats dover perhaps 67.8% of the site.

The animal-spoil (type VII) surface exposes relatively brownish, mixed A and B2 horizon material. It has a very scattered pebble pavement, and mostly has a thin (2-3 mm), fragile, nonvesicular, very fine sandy loam crust. It supports a prominent growth of small annuals after the winter precipitation (viewed 5/19/76), whereas the type V and type VI pebble paved surfaces are almost barren.

Soil Profile Features: The soil at this site is rather similar to that at the Crystal Springs site, except that it is a Paleorthid, rather than a Durorthid, that the petrocalcic horizon is continuously cemented with a thick, extremely hard lamellar cap rather than nodular-very coarsely platy, and except that the solum is somewhat coarser textured. Both soils have their finest, most silty textures in the Av horizon, rather than the B2 horizon; both are violently effervescent and strongly alkaline throughout; both have shallow pans and lack argillic horizons.

Illustrative pedon of the loamy-skeletal, carbonatic (?), thermic, shallow, Typic Paleorthid at the Blue Diamond site.[1]

Horizon (1)	Depth cm (2)	Color Dry (3)	Color Moist (4)	Texture (5)	Structure (6)	Consistence Dry (7)	Consistence Moist (8)	Consistence Wet (9)	1:5 pH (10)	CaCO3 (11)	Roots (12)	Boundary (13)	Coarse Fragments % vol. (14)
Pem	1-0	...	...	1-4 cm dia. pebbles	"m"	--(embedded in Av)--			NA	NA	none	vai	>95
Av[2]	0-6	10YR 7/3	7.5YR 4/3	sil	m	h	fr	vs/p	8.8	ev	none	as	<10
B21	6-25	7.5YR 6/3	7.5YR 4/3	gvfsl	m	vsh	fr	ss/ps	9.2	ev	few	cw	35
B22ca	25-46	7.5YR 6/3	7.5YR 6/3	gl	m	sh	fr	so/po	9.4	ev	few	vaw	40
C1cam	46-50	10YR 8/2	10YR 7/2	NA	m	--------cs--------			...	ev	...	...	>50

[1] See key to morphological abbreviations at the end of this appendix. Type V soil surface; microplain - flat position.

[2] With fine and coarse (1-2.5 mm dia.) vesicles.

KEY TO ABBREVIATIONS OF MORPHOLOGICAL TERMS FOR PEDON DESCRIPTIONS

1. Horizon Notation Suffixes

ca - pedogenic calcium carbonate
m - cemented or indurated
si - pedogenic silica
t - pedogenic clay accumulation

2. Color - Munsell color notation used

3. Soil Texture

st - stony
k - cobbly
g - gravelly
vcos - very coarse sand
cos - coarse sand
s - sand
fs - fine sand
vfs - very fine sand
ls - loamy sand
(+) - rel. high clay for class
l - loam
sl - sandy loam
sil - silt loam
scl - sandy clay loam
sicl - silty clay loam
cl - clay loam
sc - sandy clay
sic - silty clay
c - clay
(-) - rel. low clay for class

4. Structure

Grade

m - massive (structureless)
sg - single grain (structureless)
1 - weak
2 - moderate
3 - strong

Size

vf - very fine
f - fine
m - medium
c - coarse
vc - very coarse

Type

gr - granular
cr - crumb
pl - platy
pr - prismatic
cpr - columnar
abk - angular blocky
sbk - subangular blocky

5. Consistence

Dry

lo - loose
so - soft
sh - slightly hard
h - hard
vh - very hard
eh - extremely hard

Moist

lo - loose
vfr - very friable
fr - friable
fi - firm
vfi - very firm
efi - extremely firm

Wet stickiness

so - nonsticky
ss - slightly sticky
s - sticky
vs - very sticky

Wet plasticity

po - nonplastic
ps - slightly plastic
p - plastic
vp - very plastic

Cementation

cw - weakly cemented
cw - strongly cemented
ci - indurated

6. Soil pH

5.1 - 5.5 strongly acid
5.6 - 6.0 medium acid
6.1 - 6.5 slightly acid
6.6 - 7.3 neutral
7.4 - 7.8 mildly alkaline
7.9 - 8.4 moderately alkaline
8.5 - 9.0 strongly alkaline
above 9.0 very strongly alkaline

7. $CaCO_3$ test with 10% HCl

eo - non effervescent
ve - very slightly effervescent
e - slightly effervescent
es - strongly effervescent
ev - violently effervescent

8. Roots

Detailed description

Diameter classes

mi - micro, less than 0.75 mm
vf - very fine, 0.075 to 1 mm
f - fine, 1 to 2 mm
m - medium, 2 to 5 mm
co - coarse, greater than 5 mm

Abundance classes

v1 - very few
1 - few
2 - plentiful
3 - abundant

Gross description of Abundance

3 - numerous (undifferentiated diameter classes)
2 - many
1 - few
0 - none

9. Horizon Boundaries

Distinctness

va - very abrupt - transition less than 5 mm
a - abrupt - transition less than 1 inch
c - clear - transition 1 to 2½ inches
g - gradual - transition 2½ to 5 inches
d - diffuse - transition greater than 5 inches

Topography

s - smooth
w - wavy
i - irregular
b - broken

10. Coarse Fragments (dominant size class)

g - gravel
k - cobbles
st - stones

APPENDIX II

Soil textures, pH, and organic matter contents of soils from the four seedling sites.

Appendix II. Fractions of sand, silt, and clay of coppice and interspace pedon horizons at Lower Coils Creek.

Soil	Horizon	Thickness cm	Fraction, % Sand	Silt	Clay
Interspace (Type III)	A11v	4	44	36	20
	A12	8	37	39	24
	A3	16	35	43	22
	B21t	22	26	30	44
	B22t	17	29	31	40
	B23tca	10	50	26	24
	Clsicam	10+	66	26	8
Coppice (Type I)	A11	7	55	33	12
	A12	14	30	42	18
	A13	13	37	43	20
	A2	9	42	38	20

Appendix II. Fractions of sand, silt, and clay of coppice and interspace pedon horizons at Upper Coils Creek.

Soil	Horizon	Thickness cm	Fraction, % Sand	Silt	Clay
Interspace (Type III)	A11v	3	29	49	22
	A12	14	25	43	32
	A2	7	28	44	28
	B2t	19	17	29	54
	B22tca	12	16	30	54
	IIB3casi	19	53	29	18
Coppice (Type I)	A11	4	36	48	16
	A12	9	27	53	20
	A2	5	26	50	24

Appendix II. Fractions of sand, silt, and clay of coppice and interspace pedon horizons at Panther Canyon.

Soil	Horizon	Thickness cm	Fraction, % Sand	Silt	Clay
Interspace (Type III)	A11v	4	47	37	16
	A12	13	37	43	20
	B2t	17	37	43	20
	C1ca	28	33	51	16
	IIB21tcab	42	32	36	32
	IIIB22tcab	16+	50	24	26
Coppice (Type I)	A11	10	46	38	16
	A12	17	41	41	18
	B2t	17	41	41	18

Appendix II. Fractions of sand, silt, and clay of coppice and interspace pedon horizons at Paradise Valley.

Soil	Horizons	Thickness cm	Fraction, % Sand	Silt	Clay
Interspace (Type III)	A111v	2	42	46	12
	A112	6	44	44	12
	A12	10	31	49	20
Coppice (Type I)	A11	4	42	44	14
	A12	13	33	48	19
	A2	11	31	49	20
	B2t	17	37	31	32
	B22tca	13	31	37	32
	B23tca	28	25	29	46
	B3casi	16	56	25	19
	C1sicam	4+	78	12	10

Appendix II. Percent organic matter and pH of copice and interspace pedon horizons at Lower Coils Creek.

Soil	Horizon	Organic Matter %	Saturated Paste	1:5 Suspension
Interspace (Type III)	A11v	1.61	6.7	7.7
	A12	1.04	7.0	7.8
	A3	.82	7.1	8.2
	B21t	.60	7.0	8.4
	B22t	.61	7.2	8.6
	B23tca	1.05	7.5	8.9
	C1sicam	1.09	8.0	9.1
Coppice (Type I)	A11	3.60	7.2	8.1
	A12	1.87	7.5	8.3
	A13	1.06	7.5	8.4
	A2	.66	7.6	8.5

Appendix II. Percent organic matter and pH of coppice and interspace pedon horizons at Upper Coils Creek.

Soil	Horizon	Organic Matter	pH	
		%	Saturated Paste	1:5 Suspension
Interspace (Type III)	A11v	2.12	7.0	8.0
	A12	1.45	7.0	8.2
	A2	.56	7.1	8.4
	B2t	.82	7.0	8.7
	B22tca	.92	7.4	9.1
	IIB3casi	1.04	7.6	9.3
Coppice (Type I)	A11	5.82	6.9	7.6
	A12	1.70	6.9	8.0
	A2	.82	7.0	8.4

Appendix II. Percent organic matter and pH of coppice and interspace pedon horizons at Panther Canyon.

Soil	Horizon	Organic Matter	pH	
		%	Saturated Paste	1:5 Suspension
Interspace (Type III)	A11v	1.27	7.7	8.3
	A12	1.06	7.7	8.8
	B2t	.71	7.6	9.1
	C1ca	.28	8.6	9.9
	11B21tcab	.38	8.1	9.7
	111B22tcab	.22	8.0	9.4
Coppice (Type I)	A11	4.02	7.4	8.0
	A12	1.09	7.9	8.8
	B2t	.50	7.9	9.2

Appendix II. Percent organic matter and pH of coppice and interspace pedon horizons at Paradise Valley.

Soil	Horizon	Organic Matter	pH	
		%	Saturated Paste	1:5 Suspension
Interspace (Type III)	A111v	.55	7.8	9.1
	A112	.22	8.0	9.2
	A12	.56	7.6	8.8
Coppice (Type I)	A11	3.46	6.8	7.7
	A12	.83	7.4	8.4
	A2	.44	7.5	8.7
	B2t	.66	7.6	9.0
	B22tca	.60	7.6	9.3
	B23tca	.66	7.6	9.1
	B3casi	.50	7.4	8.0
	C1sicam	.61	7.9	8.9

Appendix III. Mean percent emergence of crested wheatgrass, squirreltail, and Thurber needlegrass in coppice dune and dune interspace soils on unplowed and plowed treatments at Lower Coils Creek.

Seeding Treatment	Percent Emergence[1/]		
	Unplowed		Plowed
	Coppice	Interspace	
	Crested wheatgrass		
Standard drill	21.6 b	10.8 de	18.4 b
Deep-furrow drill	30.8 a	8.4 d-f	23.7 a
Broadcast - simulated cow trampling	4.4 e-g	3.9 fg	6.2 e-g
Broadcast - no simulated cow trampling	0.3 g	0.2 g	0.7 h
	Squirreltail		
Standard drill	16.5 bc	6.0 e-g	9.2 d-f
Deep-furrow drill	21.6 b	4.8 e-g	16.3 bc
Broadcast - simulated cow trampling	3.1 fg	1.3 g	4.4 f-h
Broadcast - no simulated cow trampling	0.5 g	0.5 g	0.2 h
	Thurber needlegrass		
Standard drill	10.8 de	2.7 fg	2.8 gh
Deep-furrow drill	13.2 cd	3.0 fg	4.8 e-h
Broadcast - simulated cow trampling	0.0 g	0.0 g	0.8 h
Broadcast - no simulated cow trampling	0.0 g	0.3 g	0.3 h

1/ Emergence means within unplowed and plowed treatments followed by the same letter are not significantly different at the .05 level of probability as determined by Duncan's Multiple Range Test

Appendix IV. Mean percent emergence of crested wheatgrass, squirreltail, and Thruber needlegrass in coppice dune and dune interspace soils on unplowed and plowed treatments at Upper Coils Creek.

Seeding Treatment	Percent Emergence[1/]		
	Unplowed		Plowed
	Coppice	Interspace	
	Crested wheatgrass		
Standard drill	26.3 a-e	14.5 d-g	24.8 a-c
Deep-furrow drill	40.5 a	16.7 d-g	27.9 ab
Broadcast - simulated cow trampling	19.0 c-g	11.5 e	18.7 b-e
	Squirreltail		
Standard drill	23.6 b-f	7.3 g-h	14.6 c-f
Deep-furrow drill	38.6 ab	14.7 d-g	19.8 b-d
Broadcast - simulated cow trampling	30.4 a-d	14.2 d-g	11.6 d-g
Broadcast - no simulated cow trampling.	7.8 f-h	2.8 gh	0.6 h
	Thurber needlegrass		
Standard drill	16.6 d-h	3.1 gh	6.7 f-h
Deep-furrow drill	16.5 d-h	5.7 gh	14.0 d-f
Broadcast - simulated cow trampling	18.7 c-g	33.6 a-c	8.8 e-h
Broadcast - no simulated cow trampling	5.8 gh	1.1 h	0.8 h

1/ Emergence means within unplowed and plowed treatments followed by the same letter are not significantly different at the .05 level of probability as determined by Duncan's Multiple Range Test.

Appendix V. Mean percent emergence of crested wheatgrass, squirreltail, and Thurber needlegrass in coppice dune and dune interspace soils on unplowed and plowed treatments at Panther Canyon.

Seeding Treatment	Percent Emergence 1/		
	Unplowed		Plowed
	Coppice	Interspace	
		Crested wheatgrass	
Standard drill	14.3 b-e	0 2/ f	13.1 b-e
Deep-furrow drill	24.7 a	5.7 ef	16.5 bc
Broadcast-simulated cow trampling	21.5 ab	6.0 d-f	25.8 a
Broadcast-no simulated cow trampling	2.0 f	0.3̂ f	5.3 gh
		Squirreltail	
Standard drill	8.9 c-f	0 2/ f	8.0 e-h
Deep-furrow drill	16.0 a-d	8.0 c-f	13.8 b-e
Broadcast-simulated cow trampling	16.5 a-c	10.0 c-f	16.9 bc
Broadcast-no simulated cow trampling	3.0 f	2.0 f	3.7 gh
		Thurber needlegrass	
Standard drill	5.2 ef	0 2/	3.3 gh
Deep-furrow drill	5.4 ef	0.6 f	3.1 f-h
Broadcast-simulated cow trampling	13.3 b-e	6.7 d-f	11.2 c-f
Broadcast-no simulated cow trampling	2.3 f	0 2/ f	2.1 gh

1/ Emergence means within unplowed and plowed treatments followed by the same letter are not significantly different at the .05 level of probability as determined by Duncan's Multiple Range Test.

2/ No interspace soil was present.

Appendix VI. Mean percent emergence of crested wheatgrass, squirreltail, and Thurber needlegrass in coppice dune and dune interspace soils on unplowed and plowed treatments at Paradise Valley.

Seeding Treatment	Percent Emergence 1/		
	Unplowed		Plowed
	Coppice	Interspace	
	Crested wheatgrass		
Standard drill	32.4 ab	33.7 ab	25.8 b
Deep-furrow drill	41.4 a	8.7 cd	11.4 cd
Broadcast-simulated cow trampling	14.7 c	3.8 cd	0.8 e
Broadcast-no simulated cow trampling	2.3 d	0.4 d	4.7 e
	Squirreltail		
Standard drill	40.0 ab	29.3 b	12.3 cd
Deep-furrow drill	36.6 ab	10.6 cd	7.2 de
Broadcast-simulated cow trampling	8.0 cd	4.8 cd	0.4 e
Broadcast-no simulated cow trampling	2.2 d	1.8 d	1.8 e
	Thurber needlegrass		
Standard drill	3.7 cd	1.8 d	1.7 e
Deep-furrow drill	5.8 cd	2.5 d	1.7 e
Broadcast-simulated cow trampling	9.3 cd	0.5 d	0.5 e
Broadcast-no simulated cow trampling	1.2 d	0.2 d	0.0 e

1/ Emergence means within unplowed and plowed treatments followed by the same letter are not significantly different at the .05 level of probability as determined by Duncan's Multiple Range Test.

Appendix VII. Mean percent frequency of established grass and shrub plants in 1976 on the plowed treatment at the four study sites in relation to seeding techniques. Plots were seeded Fall, 1974.

Location and Species	Percent Frequency[1/]	
	Deep furrow drill	Standard drill
Lower Coils Creek		
Crested wheatgrass	91.6 j	88.6 j
Squirreltail	79.0 h-j	64.6 hi
Thurber needlegrass	28.0 d-f	23.0 c-f
Fourwing saltbush	28.4 d-g	22.8 c-f
Upper Coils Creek		
Crested wheatgrass	86.8 j	92.2 j
Squirreltail	78.0 h-j	74.8 h-j
Thurber needlegrass	22.4 b-f	17.6 b-e
Fourwing saltbush	22.4 b-f	29.6 d-g
Panther Canyon		
Crested wheatgrass	80.2 ij	88.2 j
Squirreltail	86.0 j	76.8 h-j
Thurber needlegrass	36.6 e-g	18.4 b-e
Fourwing saltbush	29.4 d-g	24.0 c-f
Paradise Valley		
Crested wheatgrass	32.4 e-g	66.4 hi
Squirreltail	32.4 e-g	44.0 g
Thurber needlegrass	10.6 a-c	8.0 ab
Fourwing saltbush	0.4 a	0.2 a

1/ Frequency means within columns or rows with the same letters are not significantly different at the .05 level of probability as determined by Duncan's Multiple Range Test.

Appendix VIII. Mean percent frequency of established grass and shrub plants in 1976 on the unplowed treatment at the four study sites in relation to seeding techniques. Plots were seeded in Fall, 1974.

Location and Species	Percent Frequency[1/]	
	Deep furrow drill	Standard drill
Lower Coils Creek		
Crested wheatgrass	70.5 o	66.9 o
Squirreltail	60.8 no	62.7 no
Thurber needlegrass	42.9 j-m	47.5 lm
Fourwing saltbush	26.4 d-i	26.9 d-i
Upper Coils Creek		
Crested wheatgrass	69.9 o	46.0 kl
Squirreltail	52.9 mn	26.1 c-i
Thurber needlegrass	27.0 d-i	22.8 c-g
Fourwing saltbush	0.1 a	0.0 a
Panther Canyon		
Crested wheatgrass	46.6 k-m	17.6 c-f
Squirreltail	36.5 h-l	7.1 a-c
Thurber needlegrass	13.1 a-c	1.1 a
Fourwing saltbush	1.3 a	0.5 a
Paradise Valley		
Crested wheatgrass	38.0 i-l	52.3 mn
Squirreltail	35.8 g-l	30.4 e-j
Thurber needlegrass	16.0 b-e	2.2 a
Fourwing saltbush	0.0 a	0.0 a

1/ Frequency means within column or rows with the same letters are not significantly different at the .05 level of probability as determined by Duncan's Multiple Range Test.

Appendix IX. Mean percent frequency of established grass and shrub plants in 1976 on the unplowed treatment at the four study sites in relation to coppice dune and dune interspace soils. Plots were seeded in Fall, 1974.

Location and Species	Percent Frequency[1/]	
	Coppice Dune	Dune Interspace
Lower Coils Creek		
Crested wheatgrass	75.1 o	62.3 l-o
Squirreltail	73.8 m-o	49.7 i-l
Thurber needlegrass	63.4 m-o	27.0 e-g
Fourwing saltbush	31.0 gh	24.3 d-g
Upper Coils Creek		
Crested wheatgrass	55.4 j-m	60.5 k-m
Squirreltail	43.6 h-k	35.4 gh
Thurber needlegrass	42.4 h-j	7.4 a-c
Fourwing saltbush	0.1 a	0.0 a
Panther Canyon		
Crested wheatgrass	53.7 j-m	10.5 a-c
Squirreltail	35.3 gh	8.3 a-c
Thurber needlegrass	14.2 b-e	0.0 a
Fourwing saltbush	1.8 ab	0.0 a
Paradise Valley		
Crested wheatgrass	61.4 l-n	28.9 fg
Squirreltail	62.4 l-o	3.8 ab
Thurber needlegrass	17.1 c-f	1.1 ab
Fourwing saltbush	0.0 a	0.0 a

1/ Frequency means within rows or columns with the same letters are not significantly different at the .05 level of probability as determined by Duncan's Multiple Range Test.

Appendix X. Mean percent emergence of three grass species in Spring, 1976 on unplowed treatment at the four study sites in relation to soil surface type and seeding method. Plots were seeded in Fall, 1975.

Surface Soil Type[1/]		Seeding Method[2/]	Lower Coils Creek	Upper Coils Creek	Panther Canyon	Paradise Valley
			Percent Emergence[3/]			
I	Crested wheatgrass	SFD	6.9 d-g	7.3 b-d	6.4 bc	3.8 a-c
		DFD	15.1 h	17.3 e	9.0 c	6.9 cd
	Squirreltail	SFD	7.0 d-g	8.0 b-d	1.4a	1.6 ab
		DFD	10.1 g	17.2 e	9.4 c	11.3 de
	Thurber needlegrass	SFD	0.3 a	1.9 ab	0.4 a	0.0 a
		DFD	0.3 a	4.8 a-c	0.2 a	0.4 a
II	Crested wheatgrass	SFD	6.0 c-f	6.6 bc	2.4 ab	2.6 ab
		DFD	8.4 fg	12.4 de	10.5 c	12.0 e
	Squirreltail	SFD	4.6 b-e	6.3 bc	1.3 ab	2.0 ab
		DFD	8.0 e-g	14.4 e	6.5 bc	7.9 c-e
	Thurber needlegrass	SFD	0.1 a	1.2 ab	0.0 a	0.0 a
		DFD	1.0 a	6.8 b-d	0.1 a	0.2 a
III	Crested wheatgrass	SFD	4.6 b-e	5.6 bc	- -	1.1 ab
		DFD	6.1 c-f	7.4 b-d	- -	10.8 de
	Squirreltail	SFD	2.9 bc	3.4 a-c	- -	1.1 ab
		DFD	6.7 c-g	8.1 cd	- -	4.7 bc
	Thurber needlegrass	SFD	0.0 a	0.6 a	- -	0.0 a
		DFD	0.0 a	3.6 a-c	- -	0.8 a

1/ Soil surface types are as described in Appendix I.
No type III was encountered at Panther Canyon.
No emergence occurred on type IV surface soil.

2/ SFD = Standard-furrow drill; DFD = Deep-furrow drill.

3/ Percent emergence means within location followed by the same letter are not significantly different at the .05 level of probability as determined by Duncan's Multiple Range Test.